SMITH-GOSS DITCH IRRIGATION PROJECT

by

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B. S. New Mexico State University, 1972

A thesis submitted to the

Faculty of the Graduate School of the

University of Colorado in partial fulfillment

of the requirements for the degree of

Master of Science

Department of Civil, Environmental, and Architectural Engineering

1984

This thesis for the Master of Science degree by

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has been approved for the Department of

Civil, Environmental, and Architectural Engineering

by

Curnutt, Donald Duane (M.S., Civil, Environmental, and Architectural Engineering)

Review and Design for Utilization of the Smith-Goss Ditch Water.

Thesis directed by Professor J. Ernest Flack

The object of this thesis is to examine the current use of both domestic and ditch water on lawn area of the University of Colorado at Boulder which is serviced by the Smith-Goss Ditch. The thesis goes on to describe, via designs, ways to maximize the utilization of Smith-Goss Ditch water by both practical and feasible means.

It was found that of the total 19.6 acres of lawn in the lower north campus area, 13.93 acres were being irrigated with domestic water through sprinkler systems and the remaining 5.64 acres were being flood-irrigated with ditch water, while utilizing 44 ac-ft/yr and 22 ac-ft/yr, respectively.

The University has an adjudicated decree for 2.75 cfs yielding 990 ac-ft/yr which, except for the 22 ac-ft, has been abandoned due to non-use. The University in the past attempted to utilize the Smith-Goss water. One serious attempt failed in 1976 when the pumping/filtration plant built in conjunction with the Newton Court housing complex failed to function properly. The failure resulted because the design did not provide an automatic backflush system. By retrofitting this pumping plant, immediate use of ditch water could begin and through the installation of 4" diameter piping distribution

and tie-in system running from the pumping facility through or around each of the other housing complexes in the lower north campus area, all areas could be serviced.

It was found that the University could, over a twenty-year period, save $164,700 by retrofitting, distributing and utilizing Smith-Goss water. This savings is the sum of the domestic water cost of $122,700 plus a net gain of $42,000 for using ditch water. The net gain for using ditch water is due mainly to establishing a legal consumptive use for a water right which in turn has a large resale value.

The form and content of this abstract are approved. I recommend its publication.

DEDICATION

The work and results of this thesis are dedicated to Mr. Howard Berry during his last years with the University of Colorado at Boulder who became aware of and stressed the development of an extremely valuable, unused asset of the University--the ditch, irrigation water. Mr. Berry's concern and persistent follow-through brought this unuse to the attention of those people with the ability to change University policies relating to water use and as a direct result of his continual awareness and drive, the work under this thesis was requested.

ACKNOWLEDGMENT

I wish to express my thanks and appreciation to the United States Navy and especially the Civil Engineer Corps which has given me the opportunity to expand my personal and professional development by achieving the higher education acquired while accomplishing this thesis and the coarse work required in obtaining the Master in Science (MS) degree.

My sincere appreciation to Dr. J. Ernest Flack, Professor of Civil Engineering under whose guidance this study was carried out, and who reviewed and offered valuable comments on the thesis.

My extreme gratitude and love to my wife and children for their continuous unquestioned support and sacrifice given throughout the time required in obtaining this further education.

I also wish to thank my devoted friend and typist Corazon Abitan for her untiring efforts and assistance.

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GENERAL INTRODUCTION

Introduction

"Wise-water use, including irrigation, in many countries is an old art - as old as civilization - but for the whole world it is a modern science - the science of survival."[1] Historically, civilization has followed the development of irrigation and wise-water use and is assured of its perpetuity as long as it is intelligently practiced.

The Spaniards on their first entrance into Mexico, Peru, and many of the Central American countries found elaborate provisions for storing and conveying water supplies which had been in use for many, many generations. At the same time there were established water systems in the southwestern United States. With the influx of Europeans to the North American continent in the late eighteenth and nineteenth centuries and the mass migration and settlement of the Southwestern United States, a need arose to re-establish and maximize the use of water supplies.

In July 1847 the Mormon pioneers began one of the first major water distribution and irrigation systems in the Salt Lake Valley. Shortly thereafter, other areas began a rapid growth and development period. It was soon found that water was a relatively scarce but

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[1]Gulhati, N.D., "Worldwide View of Irrigation Developments", Proc. Am. Soc. Civil Eng., No. 1951, September 1958.

crucial commodity in the development and growth of the Southwest.

As Colorado began to populate in the last century, water rights were established and appropriated on a first-come, first-served basis. As the population of Colorado's eastern slopes began to increase, the demand for water increased also. Agriculture, industry, mining, and domestic use began to compete for the limited water available.

The University of Colorado at Boulder acquired very senior water rights on Boulder Creek. For many years, the University used its water rights to irrigate farm land in its possession. As urbanization and University expansion continued, the farmland was converted to facility sites. With relatively inexpensive and easily accessible water available through the local municipal source, the University landscaped much of the area surrounding its facilities. The University, over the years, has continued to use less and less of its irrigation/appropriated waters and has used more and more treated domestic water from the local municipal supplier.

The University increased demand for domestic water has been accompanied by large increases in municipal water rates over the past twenty years as seen by the following incremental five-year listing.

	Cost per 1000 gallons
July 1960	$0.1656
July 1965	0.3510
July 1970	0.3657
July 1975	0.4403
July 1980	0.4697

Where water use is concerned, the University has had problems in making maximum use of its limited funds. In 1977 approximately 75 percent of the total of 1,039 acre-feet of irrigation water required to water University grounds was purchased from the City of Boulder's domestic water supply.[2] Applying 1980 prices of $0.4697/1000 gallons (or $153.04 per acre-foot) the total cost of irrigation water is $159,000. The equivalent volume of irrigation water is currently owned by the University as raw ditch water from Boulder Creek and delivered through combined ditch companies has an annual assessment of $1,621.88 and is available to irrigate the same area. The $1,621.88 and is paid annually whether water is used or not.

Increased costs of domestic water dictate that the University capitalize upon the "free" ditch water available. The water, as delivered to the University in open ditches, is generally not suitable nor accessible for application through the existing sprinkler irrigation systems. To make the water suitable and accessible for use certain fixed and varied costs would be incurred.

The University has requested that this study be conducted to evaluate current domestic and ditch water use for irrigation in the lower north campus area and to consider the possibilities of converting the domestic uses to ditch water by altering or further developing existing irrigation facilities to accommodate the use of appropriated water.

The lower north campus, shown in Figure I, is bounded on the south by Boulder Creek, Folsom Street on the east, Arapahoe Street on

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[2]AIC Associated Irrigation Consultants, "University of Colorado Landscape Water Analysis" of 30 June 1977.

the north, and Fifteenth Street on the west. This area of the campus is occupied by a portion of the University student and staff housing, Athens Court, Faculty/Staff Court, Marine Court, and Newton Court. There is also one athletic practice field which is used for football practice and is being considered for future overflow parking for major sports activities at the University stadium. The are encompasses approximately 40 acres of land of which 20 acres are currently irrigated (the major part with domestic water), 5 acres lay fallow, and 15 acres are under roads, building, parking lots, and playgrounds.

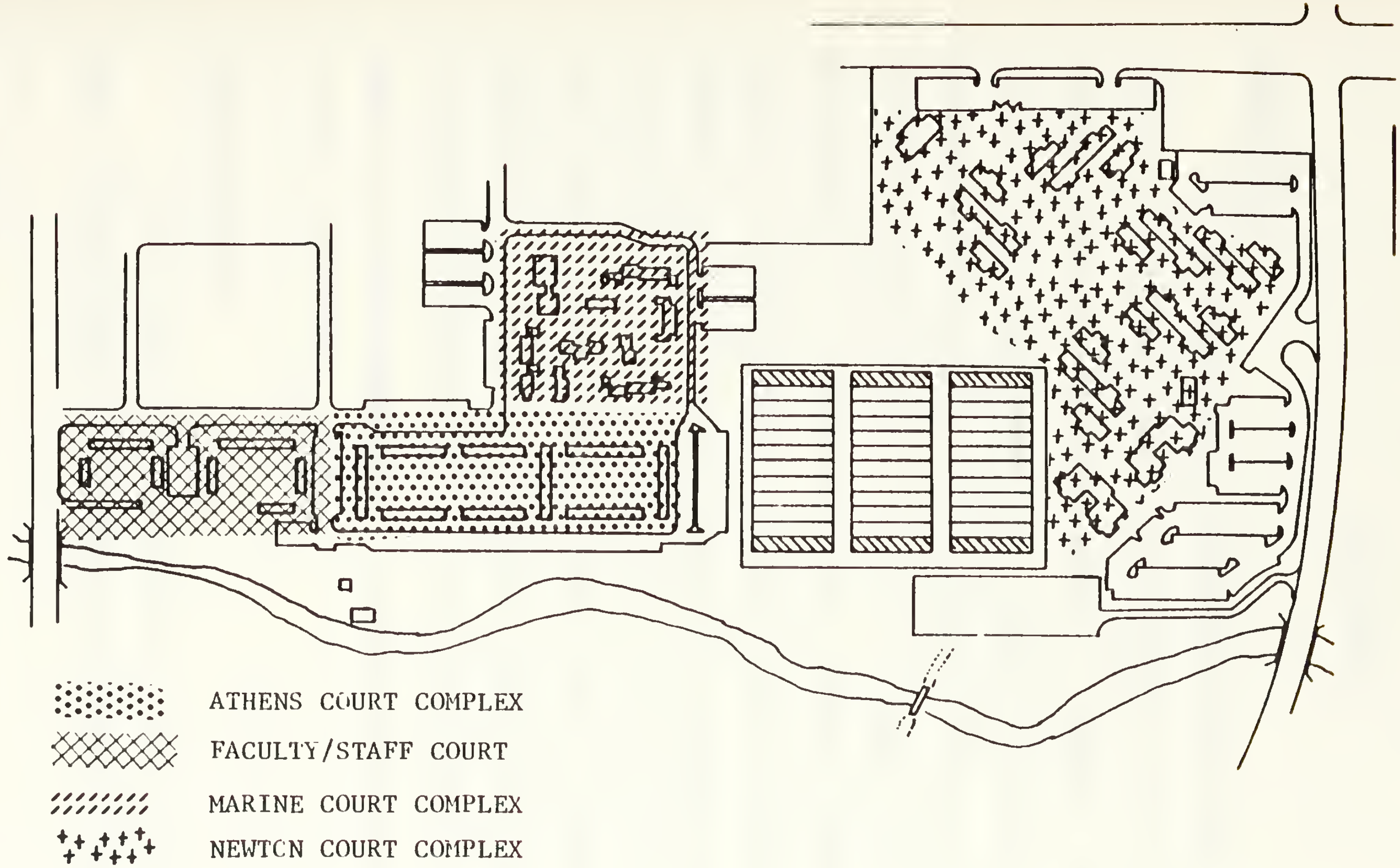

Figure 1. LOWER NORTH CAMPUS AREA

CHAPTER II

WATER USAGE

Introduction

The Smith-Goss Ditch services the lower north campus area. Over the past twenty years, a small portion of the appropriated irrigation water has been utilized for irrigation of the University grounds in this area; however, the majority of water used for that purpose has been domestic water purchased from the City of Boulder. Records have been maintained showing the annual Smith-Goss Ditch diversions[3] but no records have been maintained showing actual application of appropriated irrigation water to University grounds. Likewise, there are metered quantities of domestic water available for each housing complex. Each meter services both in-house use and lawn irrigation with no capabilities of metering quantities for each specific use. A complete review and analysis of current water uses and practices, contained herein, should be conducted to determine the quantities of both appropriated irrigation water and domestic irrigation water being used.

SMITH-GOSS DITCH

In the 2 June 1882 adjudication of water rights on Boulder Creek, the Smith-Goss Ditch Company was granted an appropriation date

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[3] Smith-Goss Ditch Diversion Records

of 15 November 1859 authorizing a diversion of water from the main stem Boulder Creek at a rate of 44.3 cfs, with a number two priority to irrigate approximately 200 acres. The University over the years acquired a total of 119 shares (55%) of the 218 total shares in the Smith-Goss Ditch Company which were used or could be used for watering approximately 109 acres of land in the north campus area.

The University used this irrigation water for some farming; however, over the years as facilities began to fill the area serviced by the ditch the farming use dwindled to nothing. The facilities that were being placed in this area were generally family housing units and as such the aesthetic requirements for landscaping were large. The most convenient way of watering the lawns was by pressurized domestic (potable) water. By the 1950's the University was using little or no irrigation water from the Smith-Goss Ditch. Nevertheless, because of concern for not abandoning its appropriated water rights, the Ditch Company insured that annual diversions were maintained. Table 1 indicates the maximum yearly diversion rates from 1950 until 1969 with the maximum diversion physically possible of 7 cfs (as limited by the size of the ditch).

TABLE I

MAXIMUM RECORDED DIVERSIONS 1950 - 1969
SMITH-GOSS DITCH
IN CUBIC FEET PER SECOND (CFS)

YEAR	CFS	YEAR	CFS	YEAR	CFS	YEAR	CFS
1950	8	1955	7	1960	7	1965	6
1951	10	1956	4	1961	6	1966	7
1952	6	1957	7	1962	5	1967	7
1953	6	1958	7	1963	7	1968	5
1954	6	1959	8	1964	6	1969	4

Considering the maximum yearly diversions of the ditch, as seen in Table 1, the Water commissioner, in 1974, recommended the adjudicated decree appropriation of 44.3 cfs be reduced. He recommended that only 5.0 cfs be appropriated to the Smith-Goss Ditch Company. The basis for the reduction of 39.3 cfs of the appropriated flow was abandonment. When an appropriator is decreed water far in excess of his needs, the failure to make any attempt to put such excess to use is held to constitute an abandonment.[4] The City of Boulder contested the recommendation of reducing the decreed flow to 5.0 cfs claiming that the twenty-year average was 6.45 cfs (7 cfs). Currently, there has been no determination of the contested 7.0 cfs versus the 5.0 cfs decree. For this study an assumed decree of 5.0 cfs will be used as the irrigation water right available to the

[4]Trelease, F. J., Water Law, 3rd Edition, p. 190.

Smith-Goss Ditch Company and of that 2.75 cfs belongs to the University of Colorado.

Diversions. There have been continuous yearly water diversions into the Smith-Goss Ditch since its foundation. The yearly diversion period has been based on seasonal weather conditions. The normal growing season in the Boulder area is from April through October. The diversion records indicate that the water was turned on as early as 9 April in 1960 and remained flowing as late as 26 October in 1958. Table II provides a twenty-year view of the diversion record for the Smith-Goss Ditch Company from 1960 through 1979. Table II identifies the yearly number of days that water was diverted into the ditch, the yearly average flow in cubic feet per second, and the yearly total quantity of water diverted in acre-feet. The table goes on to identify the portion of flow and total quantity belonging to the University of Colorado based on 55% of the shares of the ditch. The twenty-year period yields a 14,894 ac-ft total diversion (745 ac-ft yearly average) with total diversion days equaling 2,255 days (113 day yearly average). The average total ditch diversion for the twenty-year period would be 3.30 cfs.

TABLE II

SMITH-GOSS DITCH DIVERSIONS

YEAR	NO. OF DIVERTED DAYS	YEARLY AVERAGE (CFS)	YEARLY TOTAL (A/F)	UNIVERSITY SHARE (CFS)	UNIVERSITY SHARE (A/F)
1960	174	4.9	1724	2.7	948
1961	120	3.6	864	2.0	475
1962	184	3.5	1288	1.9	708
1963	181	3.6	1308	2.0	719
1964	174	3.3	1148	1.8	631
1965	140	3.2	896	1.8	493
1966	152	3.5	1085	1.9	597
1967	135	4.6	1244	2.5	684
1968	117	3.5	820	1.9	451
1968	96	4.5	864	2.5	475
1970	101	3.3	680	1.8	374
1971	77	1.7	264	0.9	145
1972	117	3.5	836	1.9	460
1973	77	1.2	186	0.7	102
1974	70	2.0	282	1.1	155
1975	117	1.9	451	1.0	248
1976	29	1.8	104	1.0	57
1977	64	1.8	226	1.0	124
1978	32	2.4	154	1.3	85
1979	98	2.4	470	1.3	285
TOTAL:	2255		14894		
AVERAGE:	113	3.3	745	1.82	402

Of the total diversion of 3.3 cfs, the University would be entitled to at least 1.8 cfs (55% of 3.3 cfs). This 1.8 cfs is, of course, less than the 2.75 cfs available based on the 5.0 cfs decreed to the Ditch Company.

Current Practice. There are approximately 20 acres of land in the lower north campus area which are currently being irrigated. The following is a breakout of the area being irrigated and its current source of irrigation water:

TABLE III

IRRIGATED AREAS

COURT	ACRES	DOMESTIC	DITCH
Athens	1.74	x	
Faculty/Staff	1.01	x	
Marine	1.33	x	
Newton	9.85	x	
Practice Field	5.64		x
TOTAL:	19.57	13.93	5.64

The athletic practice field, the only area being irrigated by ditch water, is irrigated on a random schedule which attempts to apply water once every ten days.[5] The irrigation of the practice field is accomplished by means of field distribution boxes located down the middle of the field. Figure 2 identifies the layout of the practice field and the location of the field distribution boxes. Irrigation is accomplished by using one box at a time and allowing

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[5]Interview with Lloyd Easley, Athletic Department University of Colorado at Boulder 23 March 1981.

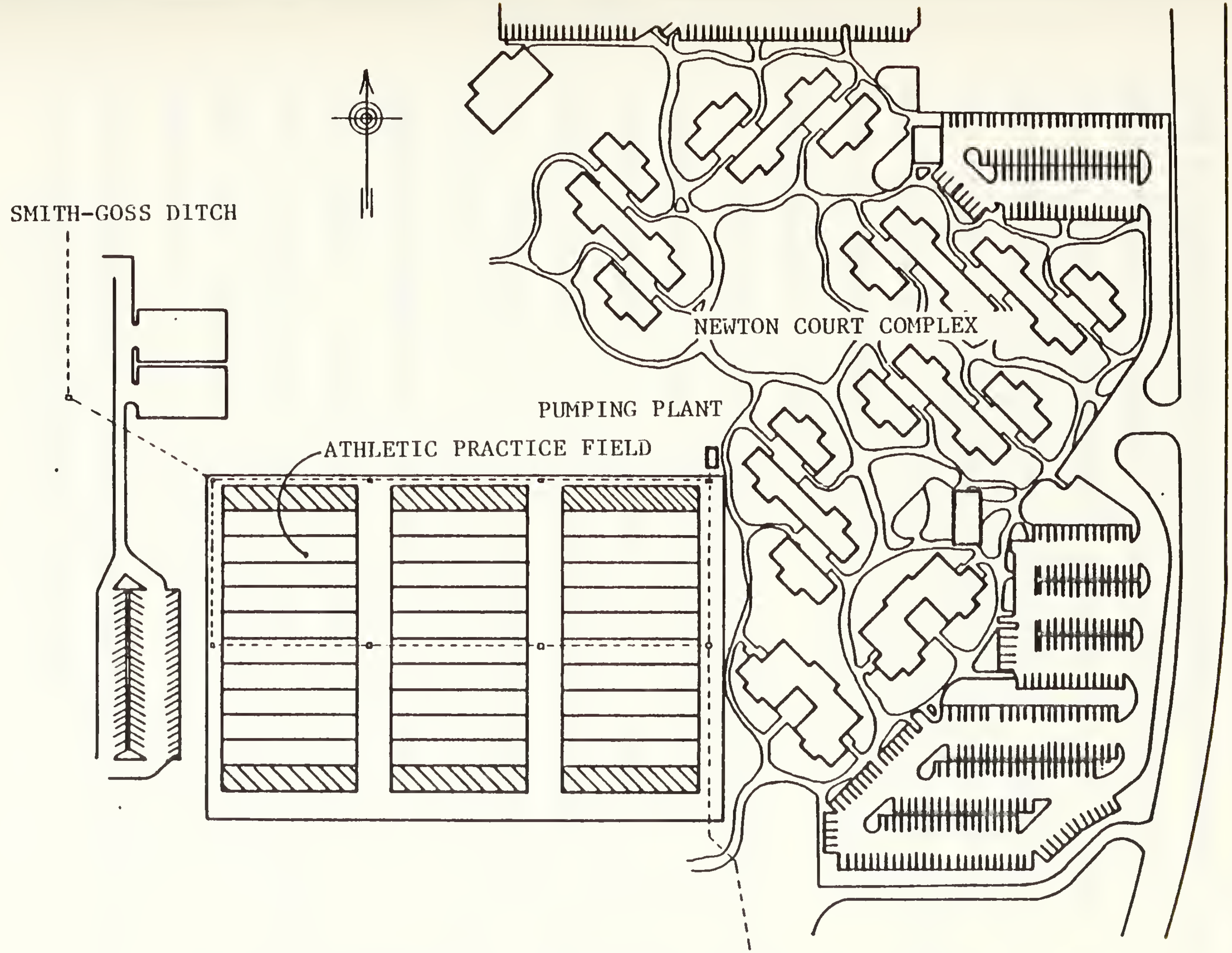

Figure 2. SMITH-GOSS DITCH AND FIELD TURNOUTS FOR THE ATHLETIC PRACTICE FIELD

the water to discharge by flooding over the field. In two seven-day periods the complete 5.6 acres is irrigated. It was found through flow measurements that water was being discharged on to the practice field at a rate of about 1.0 cfs. Applying 1.0 cfs for a total of 14 hours yields a total application of 1.17 ac-ft or a total of 2.49 inches applied to the entire 5.64 acres once every ten days. (This breaks down to a per day rate of 0.249 inches.) Applying that rate consistently for a hypothetical 180-day irrigation period, a total annual application of 44.8 inches or 21.06 ac-ft would be applied. The 21.1 ac-ft reduces to 0.12 ac-ft/day application with a continuous flow of 0.06 cfs.

By the 1970's the University of Colorado had become aware of the need to utilize the unused Smith-Goss Ditch water. When the University entered into an agreement with an architect/engineering firm for the design of the Newton Court housing complex in September 1972, they required that design incorporate a lawn sprinkler irrigation system that would accommodate the use of ditch water. That system was designed and constructed as an integral part of the Newton Court complex. The system was to irrigate 9.85 acres of landscaped area in the Newton Court complex by means of a filtration/pumping plant. Upon completion of the construction of the plant, it was found that the filtration system plugged rapidly and required excessive maintenance. It was abandoned and the sprinkler system was tied directly into the domestic water supply.

The filtration system was used for only two days. The design deficiency of the filtration/pumping plant will be addressed later.

To date, the University irrigates only the Athletic Practice Field with ditch water. Table IV compares the ditch water utilized to the ditch water available.

TABLE IV

UTILIZED VS. AVAILABLE DITCH WATER

	CFS	AC-FT/DAY	AC-FT/YEAR
Utilized	0.06	0.12	21.1
Available	2.75	5.50	990.0
Not Utilized	2.69	5.38	968.9
Percent Utilized:	2.2%		

Legal Status of the Smith-Goss Ditch Water

The University owns 55% of the shares of the Smith-Goss Ditch. The original decreed 44.3 cfs of continuous flow was reduced to 5 cfs. Of the 5 cfs currently appropriated to the ditch company the University had an entitlement continuous flow of 2.75 cfs or a total of 990 ac-ft/year available for use. Due to current and past irrigation practices, only two (2) percent of the University's appropriated water was applied to beneficial use.

> "The Colorado Water Right Determination and Administration Act of 1969 provides that for the purpose of preparing the 1974 tabulations of water rights, a ten-year failure to apply available water to beneficial use will create a rebuttable presumption of abandonment.[4]

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[4]Trelease, F. J., Water Law, 3rd Edition, p. 190

This was the basis for the 1974 recommendation for reducing the decreed Smith-Goss appropriation to 5 cfs. This same principle could be applied to the decreed 5 cfs or the University's 2.75 cfs. Current and past (well over 10 years) irrigation practices indicate that some 2.69 cfs have been abandoned or forfeited.

> When the party entitled to the use of water fails to beneficially use all or any part of the water claimed by him, for which a right of use has vested, for the purpose for which it was appropriated or adjudicated, except the waters for storage reservoirs, for a period of four (4) years, such unused water shall revert to the public and shall be regarded as unappropriated public water, provided; however, that forfeiture shall not necessarily occur if circumstances beyond the control of the owner have caused nonuse, such that the water could not be placed to beneficial use by diligent efforts of the owner.[6]

The University has not applied the total appropriated water to beneficial use; however, efforts have been made toward that goal. The ditch company has consistently made diversions into the Smith-Goss Ditch and that diverted water has continually passed through well maintained ditches owned by the ditch company and the University. The University did, in the period of time from 1972 through 1976, make an effort to utilize additional ditch water in the Newton Court

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[6]Tackett, Justice. State Ex Rel. Reynolds vs. South Springs Co. Supreme Court of New Mexico, 1969. 80 N.M. 144, 452 p.2d 478.

housing complex. The University has indicated an attempt to utilize ditch water and had no intention of abandoning its decreed water rights. The question is, has this attempt been adequate justification to protect its decreed water rights:

1. In the case of Parsons vs. Ft. Morgan Reservoir & Irrigation Company the court in its decision established that yearly turning of water into another ditch, but not using it, was a mere pretense not preventing abandonment.[4]

2. The University and Smith-Goss Ditch Company have maintained existing distribution systems and added new but unsuccessful facilities to irrigate lands; however, a diligent effort has not been sustained by the University to utilize or apply its decreed water to beneficial use.

> While upon the one hand, abandonment is the relinquishment of the right by the owner with the intention to forsake and desert it, forfeiture, upon the otherhand, is the involuntary or forced loss of the right, caused by the failure of the appropriator or owner to do or perform some act required by the statute. Forfeiture is a punishment annexed by law to some illegal act or negligence in the owner of the lands, tenements, or hereditaments, whereby he loses all his interests therein.[6]
>
> The element of intent, therefore, so necessary in the case of abandonment, is not a necessary element in the case of forfeiture. In fact, a forfeiture may be worked directly against the intent of the owner of the right to continue in possession and the use of the right. Therefore, forfeiture as applied to water rights and other rights in this

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[4]Trelease, F. J., Water Law, 3rd Edition, p. 190

[6]Tackett, Justice. State Ex Rel. Reynolds vs. South Springs Co. Supreme Court of New Mexico, 1969. 80 N.M. 144, 452 p.2d 478.

connection is the penalty fixed by statute for the failure to do or the unnecessary delay in doing, certain acts tending toward the consummation of a right within a specified time; or after the consummation of the right, the failure to use the same for the period specified by the statute.[6]

It appears that the University probably has unintentionally abandoned its right to the decreed 2.75 cfs except for that amount currently being used or applied to beneficial use at the Athletic Practice Field.

Domestic Water

The facilities occupying the lower north campus area are a portion of the University's housing complexes. The facilities found there are the Athens, Marine, Faculty/Staff, and Newton Courts which consist of a total of 574 faculty and student housing apartments. With the exception of Newton Court, all the complexes were built with the lawn irrigation system designed and constructed as an integral part of the domestic water supply. Each complex is serviced from the domestic water supply via a service main which feeds both the domestic in-house use and the irrigation sprinkler system. There is no practical way to isolate the uses and to separate the volume of water utilized for each purpose.

The Newton Court complex was originally designed to accommodate a non-potable irrigation source and as such had the sprinkler system as an independent system. The system designed and constructed to utilize ditch water never worked properly, and as a result the irrigation system was tied directly into the domestic

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[6]Tackett, Justice. State Ex Rel. Reynolds vs. South Springs Co. Supreme Court of New Mexico, 1969. 80 N.M. 144, 452 p.2d 478.

water service feeding the Newton Court complex. This tie could have been but was not made with a dedicated meter installed to identify the domestic water utilized in irrigating the Newton Court grounds. As a result, Newton Court is similar to the other housing complexes in that the water utilized for irrigation is not directly measurable and is generally unknown.

Without a direct measurement system available to simply meter the amount of domestic water applied for irrigation of grounds in the lower north campus area other systems of determining that use were required. The first method was to take the difference between summer and winter consumption and assume that difference to be applied to irrigation water. The second method was to identify the type of sprinklers found in each complex and considering the water pressure and established water schedule, estimate the applied water. Neither method can be considered a precise technique, however, they should yield a good approximation which could be used for further evaluation. A review of each method and the results follows.

Summer/winter differences. Monthly domestic water billings from 1974 were available for the housing complexes and water consumed by each complex was determined. The complex occupancy rates vary from winter highs to summer lows, therefore, the need existed to establish a winter per household consumption rate and then to assume that the same household (in-house) use would be utilized throughout the year. Table IV is a summary of the monthly per household consumption, with

quantities ranging from 7.07 thousand gallons per month (Kgal/mo) down to 4.30 Kgal/mo.

TABLE IV

MONTHLY DOMESTIC IN-HOUSE WATER CONSUMPTION PER HOUSEHOLD (K GAL/MO)

HOUSING AREA	1980	1979	1978	1977	1976	1975	1974
Athens Court	5.63	5.03	4.65	4.92	5.66	5.75	5.38
Faculty/Staff	4.73	4.59	4.30	4.76	7.07	5.96	6.56
Marine Court	5.86	5.88	5.55	5.09	5.44	5.31	5.17
Newton Court	5.55	5.46	4.89	5.13	6.77	Not	built

(Note: See Appendix 1 for detailed calculations.)

The figures in Table IV were applied to the summer occupancy rates of occupied apartments and a total monthly volume consumed by in-house domestic use per housing complex was derived. By subtracting the total summer in-house use from the summer total metered quantities, the monthly average use for irrigation per housing complex was obtained. These quantities are given in Table V. It should be noted that the data gathered from the Faculty/Staff Complex yielded inconsistent results because, on the average, more water was consumed during the winter months than was used during the summer months. These data are not included in Table V.

TABLE V

DOMESTIC WATER APPLIED FOR IRRIGATION

SUMMER/WINTER DIFFERENCES (K GAL/MO)

HOUSING AREA	1980	1979	1978	1977	1976	1975	1974	AVG
Athens Court	737	183	257	270	376	563	784	453
Faculty/Staff	-	-	-	-	-	-	-	-
Marine Court	393	-	354	198	331	323	472	345
Newton Court	1477	1066	1112	733	830	-	-	1048

(Note: See Appendix I for details.)

Estimate by design and water schedule. The analysis of the design output of the housing complexes sprinkler system consisted, first, of identifying each irrigation sprinkler lateral for each separate housing complex. It was found that there were a total of 67 different irrigation laterals: Athens Court, 21 each; Faculty/Staff, 6 each; Marine Court, 12 each; and Newton Court (including the Day Care Center), 28 each. Each lateral was identified as to the type, size, and number of sprinkler heads as well as the type, size, and lengths of the remain sizes of piping. Assuming an average working pressure (obtained from manufacturer catalog design data for the specific sprinkler heads) an average output per sprinkler head was obtained, i.e., if the manufacturers data indicated that the most commonly used sprinkler head per lateral would put out 6.0 gpm at 40 psi at low pressure and 7.3 gpm at 60 psi on the high side with the average pressure was assumed to be 50 psi with an output of 6.7 gpm.

This would also indicate an allowable pressure drop in the lateral of 20 psi. Knowing the gallon per minute output of each sprinkler head allowed computation of the total output of a particular lateral in gallons per minute. The watering schedule was then defined for each lateral of each housing complex.[7] Knowing the gallons per minute output of each lateral and the time (in minutes) of operation a total gallonage output per application could be determined. Combining lateral outputs at each separate housing complex gave the total output per irrigation application per housing complex. Table VI is a summary of the output or water applied (in gallons) to the grounds in a single watering of each housing complex. The table also indicates the area (in square feet) of grounds being watered which allows the output to be converted to an application depth in inches. Table VI data was further expanded to yield the total monthly application per housing complex.

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[7]Interview with Pete Devani, Housing Grounds Maintenance Director, University of Colorado on 29 June 1981.

TABLE VI

DOMESTIC WATER APPLIED FOR IRRIGATION

ESTIMATED BY DESIGN AND WATER SCHEDULES

HOUSING AREA	APPLIED (GALS)*	AREA SF	APPLICATION IN INCHES*	MONTHLY (KGAL/MO)
Athens Court	44,848	75,968	0.95	403.6
Faculty/Staff	22,880	44,006	0.83	205.9
Marine Court	21,981	57,731	0.61	197.8
Newton Court	156,932	428,916	0.59	1412.4

*Per application

Comparative Analysis. The results of the two methods are compared in Table VII. The two systems yield fairly consistent data for both Athens and Newton courts. The comparison of data for Marine Court indicates that the two techniques employed may not truly be reflective of actual application; however, the quantities of water applied per application, either 1.07 inches or 0.61 inches, are comparable to the rates being applied at Athens Court or Newton Court.

TABLE VII

DOMESTIC WATER APPLIED FOR IRRIGATION

SUMMER/WINTER VS. ESTIMATED BY DESIGN AND SCHEDULE

HOUSING AREA	TECHNIQUE	KGAL/ MONTH	INCHES/ MONTH	KGAL/ APPL.	INCH/ APPL.	SEASONAL IN/SEASON
Athens Court	Summer/Winter	453	9.57	50	1.06	57.42
	Estimated	404	8.55	45	0.95	51.30
	Difference	+ 49	+1.02	+ 5	+0.11	--
Faculty/Staff	Summer/Winter	--	--	--	--	--
	Estimated	205	7.47	2.3	0.83	44.82
	Difference	--	--	--	--	--
Marine Court	Summer/Winter	345	9.57	38	1.07	57.54
	Estimated	198	5.49	22	0.61	32.94
	Difference	+147	+4.10	+16	+0.46	--
Newton Court	Summer/Winter	1048	3.92	116	0.44	23.52
	Estimated	1412	5.31	157	0.59	31.86
	Difference	364	-1.39	- 41	-0.15	--

Application efficiencies. The objective of an agricultural irrigation system is to supply only the water required to produce or yield the desired results in crop. That principle applies to raising cotton, corn, alfalfa, permanent pastures and even lawn grasses used for landscaping, but lawns are not and should not be considered the same as agricultural crops. Urban lawn irrigation is justified on the basis of maintaining a cool, clean and green microclimate.

Agricultural crop yields can be directly correlated to the volumes of irrigation water applied. However, it is extremely difficult to equate or correlate applied irrigation water to the aesthetic appearance of lawn. As a result most lawn irrigators simply attempt to apply the least amount of water which will yield the desired results. Oftentimes, the convenience of the irrigator is the major consideration and not the volume of water required by the lawn. An example of this can be seen in Table VII where the estimated application rates vary from 0.59 inches/application to 0.95 inches/ application. The applications in each case were set so that watering cycle would be forty minutes. This is, of course, easy for the irrigator and as long as extreme costs or inefficiencies are not encountered it could be considered an acceptable practice.

A third technique should be applied to evaluate the water utilized for irrigation of lawns in the lower north campus area. That technique to identify the consumptive use of the identified lawn areas. Consumptive use is defined as the volume of water utilized by the plant, in this case the lawns. Consumptive use is generally identified in depth per day and in this study will be discussed in inches per day. Consumptive use is a function of the particular crop, management practices, and climatic conditions. Table VIII gives the results of a study relating monthly temperatures, precipitation rates, and daily consumptive use.

TABLE VIII

AVERAGE CLIMATIC DATA AND DAILY CONSUMPTIVE USE

MONTH	AVERAGE TEMP. C	AVERAGE PRECIPITATION (INCHES/DAY	AVERAGE DAILY CONSUMPTIVE USE (INCHES/DAY)
May	13.67	0.081	0.216
June	18.33	0.063	0.294
July	22.00	0.039	0.319
Aug	21.06	0.033	0.276
Sep	16.11	0.033	0.199
Oct	10.22	0.033	0.116

Figure 3 is the graphic representation of data exhibited in Table VIII. The area under the precipitation curve indicates the total average inches of rain received during the growing season (8.46 inches) and the area below the consumptive use curve is the total inches of water last to evapotranspiration during the growing season (42.60 inches). The area between the two curves is the inches of water required to be furnished by irrigation to fulfill 100% of the consumptive use requirements, the difference is 34.14 inches. That is to say that at least 34 inches of water must be applied during the entire growing season to supplement the annual rainfall to provide 100% of the annual consumptive use for the lawn areas. It is beyond the scope of this study to determine if a goal of supplying 100% of the consumptive use is required to maintain high quality lawn appearance. It is sufficient here to state that the goal of the

University's lawn irrigators and those designing the sprinkler systems is to supply the consumptive use requirements of the lawn. It should be noted that it is impossible to apply just the exact amount of water required by the plants. To supply the volume of water needed for evapotranspiration, a volume of water in excess is required. Water losses will occur because of evaporation, runoff, deep percolation, and losses in conveyance. It is beyond the scope or intent of this study to examine and define irrigation efficiencies in the existing irrigation systems, but a 75% irrigation efficiency will be utilized herein.[8] If 34.14 inches of water are required by the plant than 46 inches must be diverted for application.

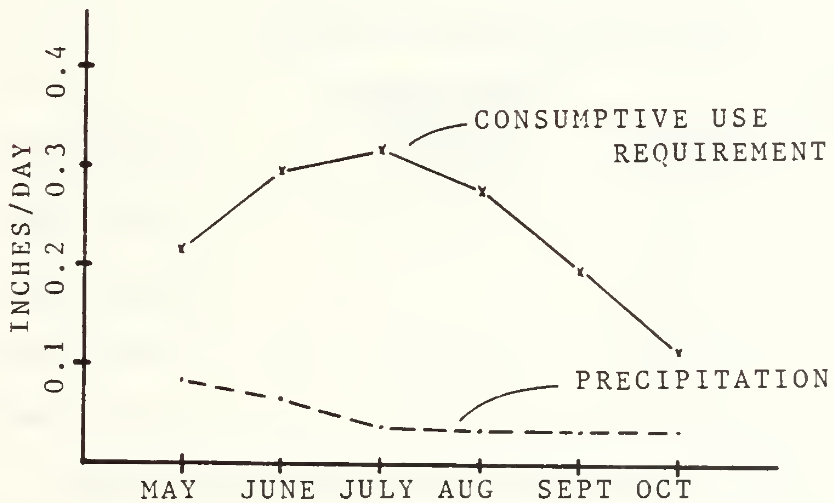

Figure 3, LAWN CONSUMPTIVE USE REQUIREMENTS

[8]Israelsen, O. W. and Hansen, V. E. Irrigation Principles and Practices, Third Edition (N.Y.: John Wiley and Sons, Inc.) p. 295.

Summary

Table IX is a summary of comparison of the seasonal application for each of the housing areas. The comparisons uses the two techniques used in computing the domestic water utilized for irrigation and compares those with the volume of water required to be applied to supplement rainfall to provide 100% of the consumptive use. The comparison indicates the water volume applied, as calculated from the difference of summer/winter volumes consummed, is in excess of required water rates except in the Newton Court housing complex. The designed estimate with the current watering schedules indicate that higher rates are applied to Athens and Faculty/Staff with quantities applied at Marine and Newton courts almost equal to the supplemental requirements.

TABLE IX

SEASONAL APPLIED WATER SUMMARY

HOUSING AREA	SUMMER/WINTER TECHNIQUE (INCHES)	ESTIMATED (INCHES)	SUPPLEMENTAL REQUIRED (INCHES)
Athens Court	57.42	51.30	34.14
Faculty/Staff	-	44.82	34.14
Marine Court	57.54	32.94	34.14
Newton Court	23.52	31.86	34.14

The data obtained by the two analysis techniques and requirements calculations support one another in defining the total annual volume of domestic water applied to irrigate the lawn areas in the lower north campus area. Table X yields a computed average

yearly volume of 44 ac-ft of domestic water applied for irrigating lawns per growing season within the lower north campus area. Coupling this 44 ac-ft with the 21 ac-ft of ditch water applied, it is recognized that approximately 65 ac-ft of irrigation water are required/applied each irrigation season.

TABLE X

SEASONAL DOMESTIC WATER APPLIED FOR IRRIGATION IN

THE LOWER NORTH CAMPUS AREA

HOUSING AREA	SUMMER/WINTER K/GAL	AC-FT	ESTIMATED K/GAL	AC-FT	SUPPLEMENTAL REQUIRED K/GAL	AC-FT	AVERAGE K/GAL	AC-FT
Athens Court	2.718	8.34	2,424	7.44	2,173	6.67	2,438	7.48
Faculty Staff	--	--	1,230	3,77	1,262	3,87	1,245	3.82
Marine Court	2,070	6.4	1,188	3.65	1,662	5.10	1,645	5.05
Newton Court	6,288	19.30	8,472	26.00	12,303	37.76	9,016	27.67
T O T A L:							14,344	44.02

CHAPTER III

UTILIZATION OF THE SMITH-GOSS DITCH WATER

Introduction

The University diverts from the Boulder Creek via the Smith-Goss Ditch an average flow of 1.82 cfs for an average period of 113 days per year yielding a 402 ac-ft/yr diversion. However, it has a recommended appropriation of 2.75 cfs for an approximate 180-day period which would yield a possible yearly diversion of 990 ac-ft. Of the 402 ac-ft diverted (or the 990 ac-ft available) only 21.1 ac-ft are applied to the Athletic Practice Field through flood irrigation practices with the remaining water returning to the Boulder Creek unutilized. In an effort to use this wasted asset and, if possible, to keep from losing the water right the University needs to apply the water to beneficial use.

About 42 ac-ft of domestic water is utilized to irrigate lawns yearly at the faculty and student housing complexes found in the lower north campus area. This usage would be the most obvious one to substitute a portion of the abundant excess of water. This study is not only to analyze the use of irrigation water but also to design methods of converting the existing irrigation system to use ditch water. This design will include an analysis of the existing system that was supposed to use at least 24.4 ac-ft/year (see Table X)

but which failed. A review of that design and alternative redesigns will be examined in this chapter.

Newton Court Pumping Facility

Existing condition. On September 14, 1972 the University of Colorado entered into an Owner-Architect Agreement with the A-B-R Partnership-Architects of 1200 Walnut Street, Denver, Colorado for architectural services pertaining to the development and construction of a University housing project, later known as the Newton Court Complex. The agreement called for the architect to complete all required studies, investigations, design specifications, and other pertinent documents to fix and describe the size and character of the entire project for both the design and construction phase. The Owner-Architect Agreement also specified that the architect would have authority to review construction bids and during construction to review all shop drawings, to interprete and correct construction documents caused by any error or discrepancy in the drawings and/or specifications, and to provide the owner any such corrections or additions as required. Monthly site visits were also called for by the architect and any consultants.

Shortly after the above agreement was made, the architect hired the services of a consultant to evaluate and prepare a study of the irrigation alternatives and flood plain requirements. McCall-Ellingson, consultant engineers of Denver, Colorado presented the studies to the A-B-R Partnership-Architect on 12 October 1972. The studies and eventual designs for the irrigation system and all other design documents for the entire project were presented to the

Design Review Board of the University of Colorado at Boulder on 1 March 1973 and with few exceptions (of which none addressed the irrigation system), the entire design package was accepted.

Later in 1973 the University (here after known as owner) entered into a contract with Weaver Construction Company of Denver to construct the housing complex. Weaver Construction Company (contractor) entered into contractual agreement with Rain-Rite Sprinklers, Inc. (subcontractor) of Boulder, Colorado to construct a filtration/pumping station and to install the lawn sprinkler system. With normal delays and general difficulties, the progress of the housing complex advanced. On 11 September 1975 the subcontractor notified the contractor of problems with the filtration/pumping plant. Apparently, the filter unit would silt up in a relatively short period of time (8 hours or less); however, the subcontractor had attempted within reason to correct the problem but felt that the problem was now the owner's. Nothing was done on this problem for the next year. As the construction phase of the contract began to draw to a close in the latter part of 1976. During September of that year, R.V. Lord and Associates, Inc., a local consultant hired by the contractor, conducted a study of the filtration/pumping plant. The reason for this study was that the owner was withholding the retainer fees on the construction contract in an attempt to get the contractor to correct the silting up problem in the unit. The owner was under the belief that the subcontractor had made some unknown construction mistake or had not taken proper precautions in keeping construction backfill from entering the filtration unit. R.V. Lord & Associates

concluded that the filtration sand did not meet the gradation standards as specified in the construction contract documents. Upon these findings the contractor had the subcontractor replaced filter material with the proper material. On 4 May 1977 the owner accepted the irrigation filter and released all monies being held.

Following the acceptance of the filtration/pumping plant, the owner's ground maintenance personnel attempted to use the unit. After only an eight-hour pumping period, the filtration unit once again silted up. The system had a potable water bypass and from that point on the filtration/pumping unit was abandoned and all future irrigations were made with potable water. No apparent effort was made to correct the problem by contacting the architect or his consultant, McCall-Ellingson. The filtration/pumping plant remains idle, however, an interest now exists to use the unit and along with that renewed interest the question arises as to why the unit never worked in the first place and what could be done to correct the problem.

Several key questions need to be addressed:

1. Was the Filtration/Pumping Plant constructed as specified?

2. Was the Filtration/Pumping Plant adequately designed?

   a. As regards Filtration Material?

   b. As regards the type of cleaning (purging) system?

3. What should be done?

In reviewing the contract files on the case, it was found that Lord & Associates, the consulting firm hired by the contractor, did a series of sieve analyses on the filter materials used to

detemine if the subcontractor had complied with the specifications. Upon finding the material in violation with the specifications, the material was removed and new material acquired. Again, Lord & Associates analyzed the material and found it inadequate; but suggested that remixing would allow the material to meet specifications. That mixing was done and it was found that the material did meet specifications. It is believed that the subcontractor did meet the requirements as specified in the construction specifications.

Knowing the subcontractor met the specifications then requires focusing upon the specifications. Are the gradation specifications correct or is there another major problem which contributed to the failure of the unit? Even if the material did meet specifications it would be highly improbable that the unit would work because of improper sizing of the filter material and the lack of a backflush system. Lord & Associates did recommend that a model be constructed to detemine the operating potential of the unit. Indications are that construction of the unit was done in accordance with the specifications but evidence submitted by Lord & Associates indicates some doubt as to the adequacy of the design specifications.

Architect liability for redesign. In the original study and design accomplished by McCall-Ellingson, consultants for the architect, which was presented to the University Design Review Board

for review and approval, the following comment was made concerning the filtration unit:

> Use of ditch water will require a means of straining out gross particles and stringy material from the water so as to prevent fouling of sprinkler heads. Straining is proposed to be accomplished by means of a manually-cleaned gravity sand filter ahead of the pumping sump. The sand filter will operate under the gravity head available in the ditch. A gate between the ditch and the filter box would be closed and the box pumped dry for maintenance of the filter, which would include cleaning the top layer of sand and occasional replenishment of sand removed during cleaning.[9]

Here, it is noted that the designers recognized that the filter would require maintenance, specifically a cleaning and removal of the top layer filter material. It was further mentioned that an occasional replacement of sand removed during cleaning. Therefore, McCall-Ellingson's design recognized the same points that were discussed by Lord & Associates in that the sand filter would plug and cleaning would be required (Lord & Associates discussed back flushing while McCall-Ellingson discussed hand-removal).

It is apparent that the University wanted an operating filtration/pumping plant and would be willing to conduct periodic maintenance but the question of daily maintenance seems to be of paramount importance.

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[9] McCall-Ellingson, "ABR Partnership Special Studies, Smith-Goss Ditch Irrigation, Boulder Creek Flood Plain at the University of Colorado - 1972 Family Housing Project". 12 October 1972.

Two differences or approaches to contractual law concerning the issue at hand must be briefly examined. Professional liability rules vary from state to state; however, most can be categorized within two categories: one of process standard and the other strict liability. The process standard (or professional standard) compares the performance of other design professionals under similar circumstances (the profession itself determines the legal standard). Strict liability rule simply states that the design professional is liable to the owner to produce a design which will yield a workable product. In reviewing the case at hand from both stances one finds:

I. A-B-R Partnership - Architects entered into an Owner-Architect Agreement where the architect was to produce a design which among other things would, through proper construction, yield a working filtration/pumping plant. Upon operation of the properly constructed filtration unit for an eight-hour period the unit silted up, requiring the unit to be handcleaned (an operation that requires at least two men working for one hour) daily to allow continual operation. To compare the facility, as designed, to the standards of other design professionals one needs to review the letter of 6 October 1976 from R.V. Lord & Associates, where, it was stated that if filter material originally placed in unit had been within specifications the unit would probably still not function. Further, upon review of technical and design manuals for rapid sand filters it is general practice to install automatic backflush systems to purge

the unit of filtrates once every twenty-four hours.[10]. (Rapid sand filters are those which have a loading rate of 2 to 5 gpm. The filtration unit in question has a loading rate of 1 gpm/SF with one pump working and 2 gpm/SF with two-pumps.) The designed filtration unit under consideration was designed as a slow sand filter--a system without a backflush system. In such a system the arrangement of sand particles is fine-to-coarse in the direction of filtration (down), and most of the impurities removed from the water collect on the top of the bed and the bed can be cleaned by mechanicallyscrapping the surface and removing about one inch of sand and sediment. However, it should be noted that slow sand filters should be used at low turbidity rates on the order of 0.05 to 0.13 gpm/SF of bed area.[11] Because of low surface rates, slow sand filters require larger areas of land and to meet a 150 gpm total output one would need a slow sand filter bed of at least 1,254 sq ft (34'x34'). The constructed filter bed had an area of 170 SF (10'x17').

II. To examine the problem from a strict liability viewpoint generally will not provide a solution because many questions still remain. The filtering/pumping plant would probably function if proper daily handcleaning occurred. The proposal as accepted by the University indicated that no automatic backflush system would be installed and a manual cleaning would have to occur. Therefore, the

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[10]Clark, Viessman, Hammer; Water Supply and Pollution Control, 1977, 3rd Edition.

[11]Clup, L. C. and Clup, R. L.; New Concepts in Water Purification, 1974, p. 53

unit performed as the architect stated beforehand that it would. However, the question of how often the cleaning should occur or what is a reasonable must be asked.

Conclusion. It is apparent that the University of Colorado at Boulder entered into a contractual agreement with A-B-R Partnership expecting, among other things, a filtration/pumping unit which would operate with reasonably minor maintenance. The University, instead, has a facility which it cannot operate because of extensive maintenance requirements. It was predicted by co-professionals that the unit would not function properly and upon review of filter design material by this author it is evident that common practice with such units is to include an automatic backflushing system. From these findings it can be concluded that the Architect, A-B-R Partnership-Architects acting in conjunction with their consultant, McCall-Ellingson, is responsible for the faulty design of the Newton Court Filtration/Pumping Facility.

It is further concluded that the University of Colorado failed to pursue its options to the Owner-Architect Agreement in that it did not present to A-B-R Partnership-Architect its finding of possible design error so that the architect could correct the faulty design or be in default of said agreement.

Recommendations. It is suggested that commencing in April/May the existing filtration/pumping unit be cleaned, serviced and a series of test pumpings be done to corroborate the earlier results. These tests can be accomplished with little expense and difficulty.

Besides determining the time required for plugging of the filter the particulate (suspended solids) load in the ditch water should be determined in order to correlate clogging time to pumping rate and particulate load. The particulate loading rate will allow predicting plugging rates for varying conditions.

If the results of the study confirm earlier findings, it is felt that A-B-R Partnership be contacted with findings and specify the University's expectation of redesign and correction of existing faulty facility. (A system which appears to be more cost efficient than an automatic backflush system is to remove existing filter material and in the filtering basin to simply construct a partial wier wall with a set of removable screens. On the exit side of the discharge pump install a commercial separator which continually separates all particulate material. This system requires a seven to ten percent loss of pumped water whereas a backflush system requires about four to six percent of filtered water for backflushing. However, the cost is far less than an automatic backflush system. (This design will be reviewed later in this chapter.)

If the architect refuses to correct the deficiency one must be cautioned here as to which direction to pursue according to the Colorado Revised Statutes (1980 Supplement) 13-8-127 - Limitations of Actions Against Architects, Contractors, Builders and Builder Vendors, Engineers, Inspectors, and Other States:

> (1)(a) All actions against any architect, contractor, builder or builder vendor; engineer, or inspection, construction, or observation of construction of any

> improvement to real property shall be brought within two years after the claim for relief arises, and not thereafter, but in no case shall such action be brought more than ten years after the substantial completion of the improvement to the real property.

The plain language of this section reflects a legislative intent to apply a shorter limitation period only to claims for personal injury or damage to property other than the defective improvement itself; in cases where claim relates to the defective improvement itself, the general statutes of limitations appropriate to contract, negligence, warranty, etc. are applicable. A Colorado case can be used here as a prime example.

> Homeowners brought action for damages for alleged negligence of engineering corporations in doing work related to construction of homes. The District Court of Denver entered summary judgment for engineering corporations on the basis that action was not brought within two years after claim arose and was therefore barred. The homeowners appealed and the Court of Appeals affirmed. The Supreme Court, Carrigan, J., held that where homeowners claims appeared to relate only to deficiencies in real property improvement itself, and homeowners did not seek damages for personal injury or harm to other real or personal property, the homeowners' claims were covered by six-year statute of limitations and not by special two-year limitations of action against architects, contractors, engineers, and inspectors, not withstanding that the homeowners' claim be based on negligence, rather than breach of contract or warranty.[12]

It is evident that upon pursuing any legal action against the Architect that the approach is not to litigate on the grounds of violation of the contract but instead one should show the design of the filter/pumping plant is defective.

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[12]Hart, Justice: Tamblyn v. Mickey & Fox, Inc. 195 Colorado, 354, 578 P. 2nd 641 (1978).

Redesign of the Filtration/Pumping Facility

The existing filtration/pumping plant as shown in Figure 4 was built of twelve-inch reinforced concrete. It consisted of a receiving/filtering basin approximately 2,040 cu-ft (16,000 gallon) with a 170 sq ft sand filter bed. The filtering of suspended particulates carried by the irrigation ditch water is required to reduce extensive wear on the pumping unit and sprinkler system as well as to avoid plugging of the sprinkler nozzles. The water would filter through a 5-foot depth of graded sands and gravel and would be conveyed through one of three 12-inch perforated vitrified clay pipes to a 6-foot by 10-foot pumping gallery. The gallery is equipped with one 15 HP, 150 gallon per minute vertical industrial electric pump. The gallery was designed and piped to accommodate two pumps, however, only one was installed under the construction contract and one was later purchased and stored as a replacement or possible auxiliary unit.

The plant was designed with concrete removable lids as well as a smaller personnel hatch over the receiving/filtering basin. These openings were designed to allow easy cleaning and removal and replacement of the filtering material.

It was found upon utilizing the new facility that the sand filter became plugged in a short period of time-- approximately eight hours. The ditch water sediment load was never determined and it was found by this author that no study of sediment was not available for Boulder Creek. With the lack of information available on sediment loading in the ditch water, an analysis of the effectiveness of the

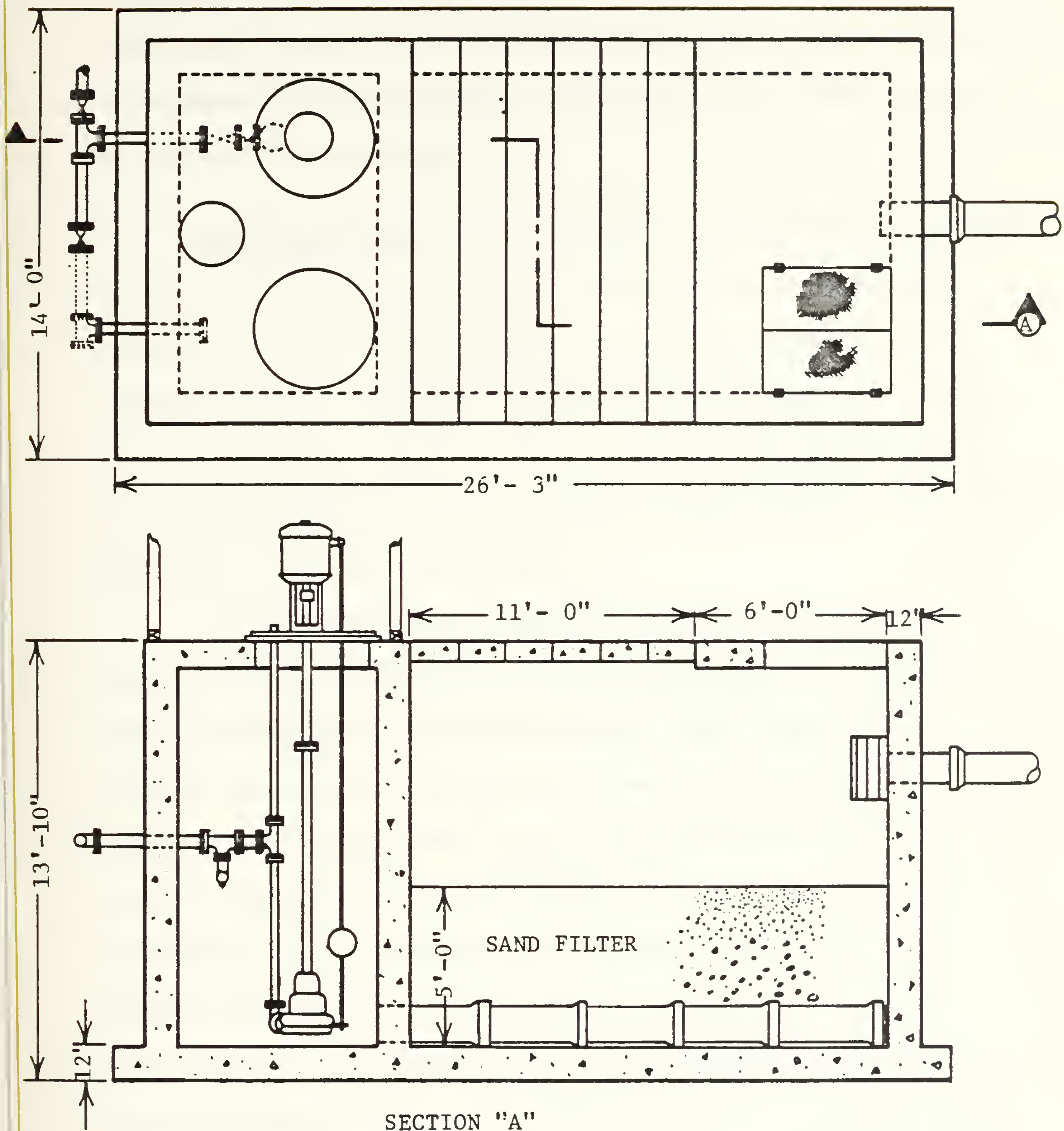

Figure 4. EXISTING NEWTON COURT FILTRATION/PUMPING PLANT

sand bed filtering system could not be completed; however with the difficulties encountered in operating the system the need is apparent that a daily cleaning was necessary. This cleaning would have to be a hand-operation taking upward to two hours time. This is unsatisfactory to the University.

Backflush system. Even though the basic design and principle of filtering incorporated in the existing Newton Court pumping facility was for a slow filter bed the actual conditions; i.e. turbidity flow of 1 gpm/sq ft, would reflect the need for a rapid sand filter with a backflush system. The existing system did not include a backflush system and a review of that system is required to determine if one could be incorporated.

As mentioned earlier slow sand bed filters accumulate sediment on top of the sand bed which can be mechanically removed. In rapid sand bed filters there is somewhat deeper penetration of particulates into the bed because of the coarser media used and the higher flow rates employed. Most of the materials are deposited and stored in the top 8 inches of a rapid sand filter bed. Rapid sand filters are cleaned by hydraulic backwashing with clean water. Backwash flow rates of 15 to 20 gpm/SF should be provided for a period from 3 to 15 minutes. During the backwash period there is a 20 to 50% increase in volume of filter material. The particulates and wash water are captured by troughs and transported, in this case, to a point downstream of the pumping plant intake from the Smith-Goss ditch.

To adapt the existing facility with a backflush system would be to provide the facility with a potable water source which could produce 2,550 to 3,400 gpm. The existing three 12-inch ventrified clay tile could not be used because they are not designed for pressurizing and their placement would not allow adequate distribution of wash water. Alterations would include the construction of catchment troughs and piping to return washed particulates and wash water back to the supply ditch.

The need to provide up to 3,400 gpm of wash water and the disposal of that volume and rate of water in and of itself restricts the use of a backflush system. Coupling that with the potential cost of retrofitting, the conclusion is that a backflush system would be impractical.

Alternate to the filtering system. Because the retrofitting of the existing pumping facility with a backflush system appeared to be impractical, a further review of that existing facility needed to be conducted to determine if that facility could be utilized. A system that was briefly discussed earlier, to simply screen and then separate particulates by using a commercial separater, will be reviewed in greater detail to determine its practicability.

The existing facility has a filter basin which could be used as a sedimentation basin. Sedimentation is the removal of suspended solids from water by gravitational settling. To produce sedimentation, the velocity of the water must be reduced to a point where solids will settle by gravity if the detention time in the sedimentation basis is great enough. The settling rate of particles is

affected by their size, shape and density as well as the fluid properties.

Water being transported through irrigation canals and ditches generally flows at velocities of 2.0 fps to 5.0 fps.[13] Normally, those velocities will transport suspended soil particles. If the water flows into a sedimentation basin, the velocity will drop greatly and sedimentation will occur.

The maximum pumping rate of the Newton Court pumping facility with one pump is 150 gpm or 20 cfm. If the maximum depth of water in the sediment basis is 10-foot with a width of 10-foot, the cross-sectional area is 100 SF. This, in turn, would yield a water velocity through the sediment basis of 0.20 fpm (20 cfm divided by 100 SF). This reduction in velocity will allow permit sedimentation of a large percentage of particulates carried by ditch water and indicates that the filtering basin in the Newton Court pumping facility could be used for a sedimentation basin.

To maximize the sedimentation in the basin, a wier wall could be installed just prior to the pumping gallery as shown in Figure 5. Particulates would be partially settled below the 4-foot level, and not be carried forwarded through the pumping system.

> A description of the settling paths of discrete particles in an ideal, rectangular basin is useful in understanding settling phenomena. In such an ideal basin, the parts of all discrete particles will be straight lines and all particles with the same settling velocity will move in parallel paths. The settling pattern shown in Figure 2-1 would be the same

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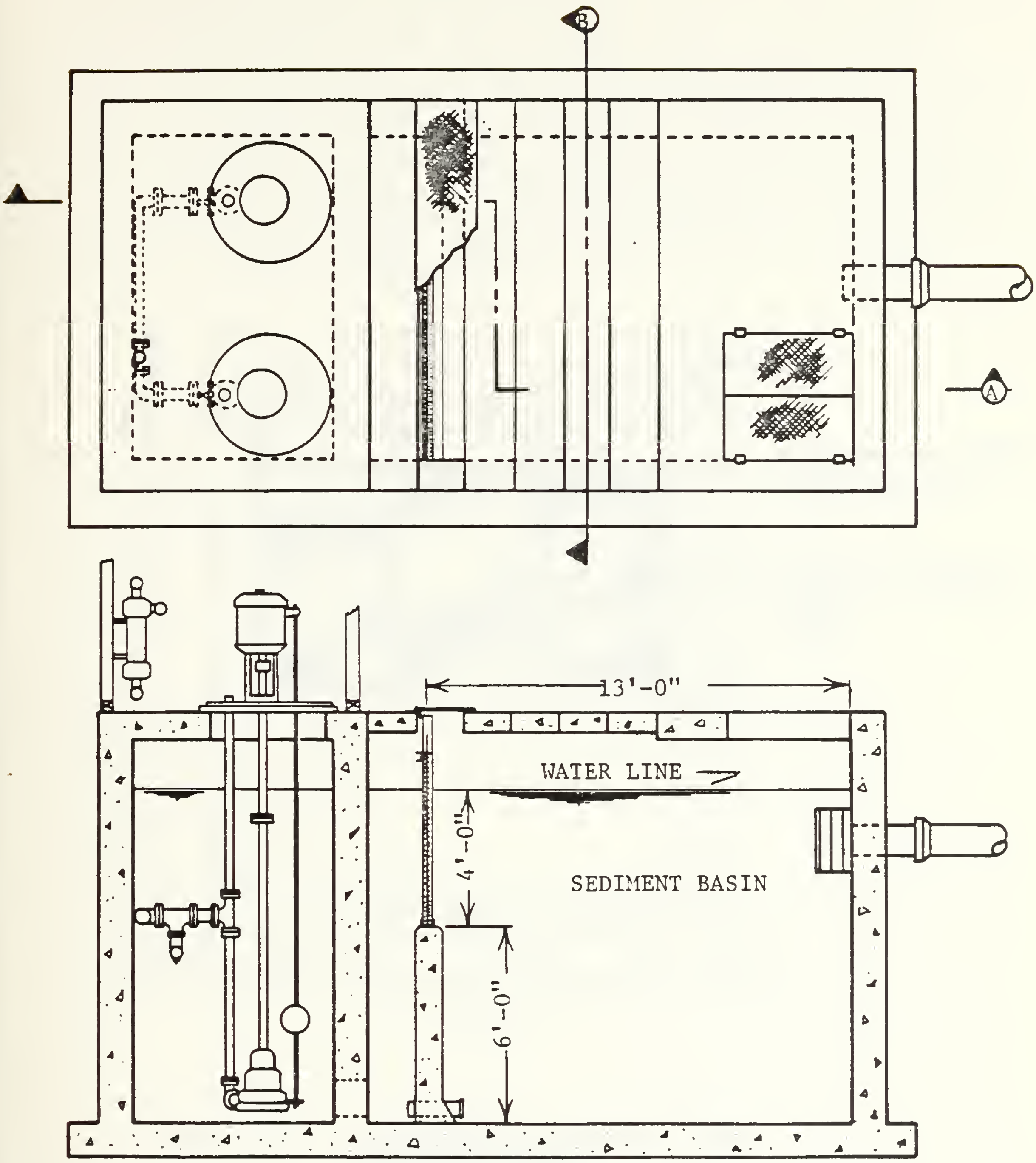
[13]Israelsen, O. W. and Hansen, V. E. Irrigation Principles and Practices, 3rd Edition (New York: John Wiley and Sons, Inc.), p. 84.



SECTION "A"

Figure 5. MODIFIED PUMPING PLANT

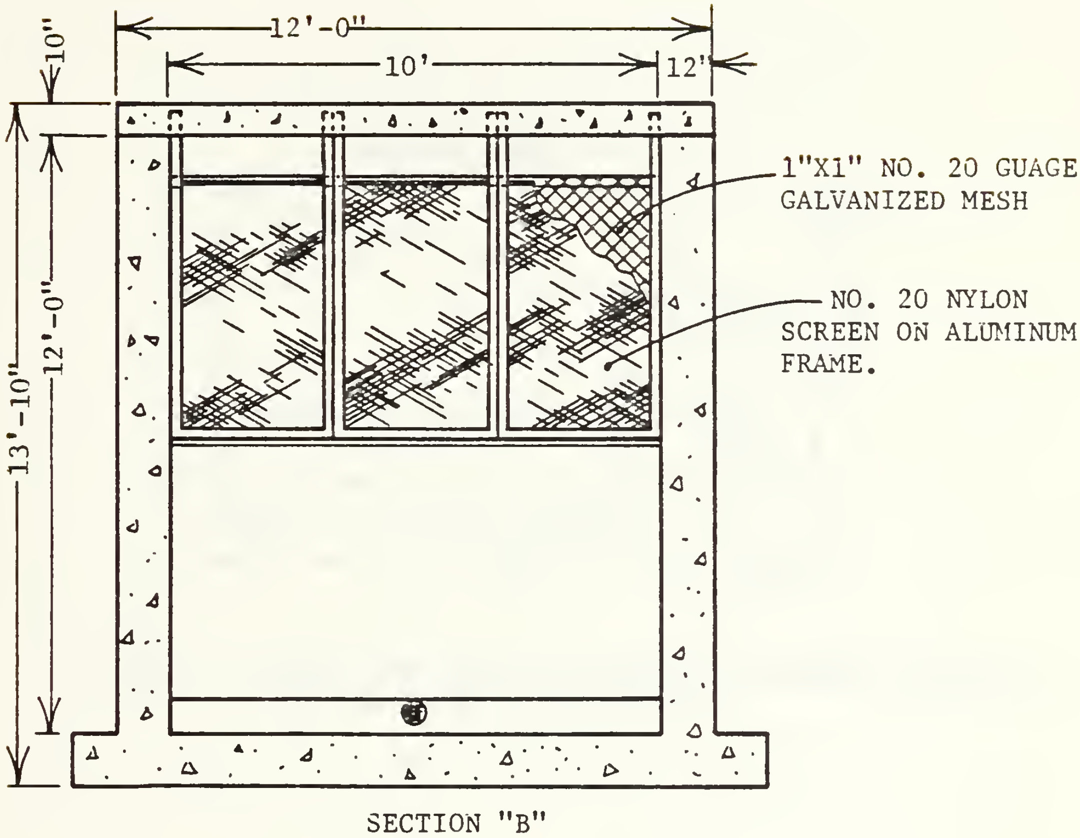


Figure 5(a). SEDIMENTATION BASIN WITH WEIR AND TRASH SCREENS

for all longitudinal sections. All particles having settling velocities, V_s, greater than V_o will fall through the entire depth, h_o, and be removed. The portion of particles with settling velocities V_s less than V_o which will be removed is equal to the ration of the velocities, V_s/V_o[1]. It can be seen from Figure 2-1 that particles with V_s less than V_o could be completely removed if false bottoms or trays were inserted at intervals--h. Without such trays, a basin with a length much greater than L_o would be required to capture these particles. It is apparent from Figure 2-1 that as the interval h is reduced, the size of basin required to remove a given percentage of the incoming settlable material decreases.[14]

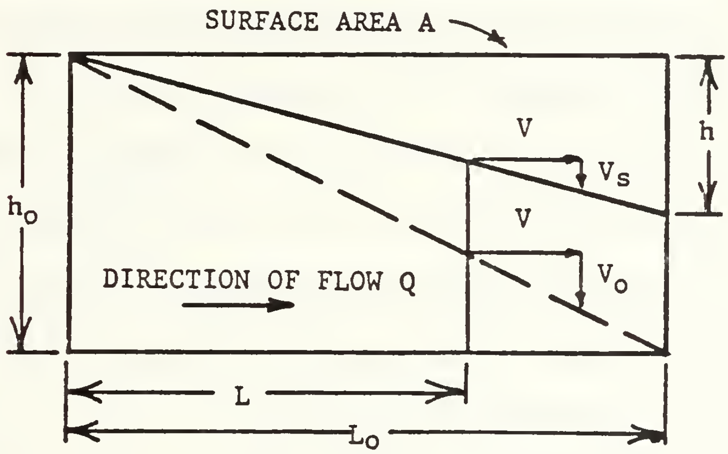


Figure 2-1 IDEALIZED SETTLING PATHS OF DISCRETE PARTICLES IN A HORIZONTAL FLOWTANK[14]

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[14]Clup, L. C. and Clup, R. L.; New Concepts in Water Purification, 1974 p. 54

In addition to the removal of particulates in the sedimentation basin, a system is needed to remove all floating debris found in the ditch water. Figure 5 shows a plan and elevation views of the existing pumping facility modified by removing the filtering system, utilizing the resulting sedimentation basin and the installation of a screen system to keep floating debris from entering the pumping gallery. The screen system uses three 20-inch removable screens adjacent to one another spanning the 10-foot width of the basin.

Once the water passes over the weir through the trash screens, it enters the pumping gallery through three 12-inch holes. The cleaned water is the pumped by the originally installed 15 HP pumps. Upon discharge from the pumps the water is routed through a commercial separator which will, at a 4 to 8 psi pressure loss, remove 98% of the remaining suspended particulates as small as 74 microns (.003 inch) and a specific gravity greater than 1.0. Figure 6 identifies the details of connecting the separator. The water that is discharged from the commercial separator is now free from all remaining particulates which will wear or plug sprinklers in the lawn sprinkler systems. Those particulates are continually being removed as the system operates and returned to the irrigation ditch with a small 5 gpm flow. The costs associated with this alternate system will be reviewed and analyzed in a later chapter.

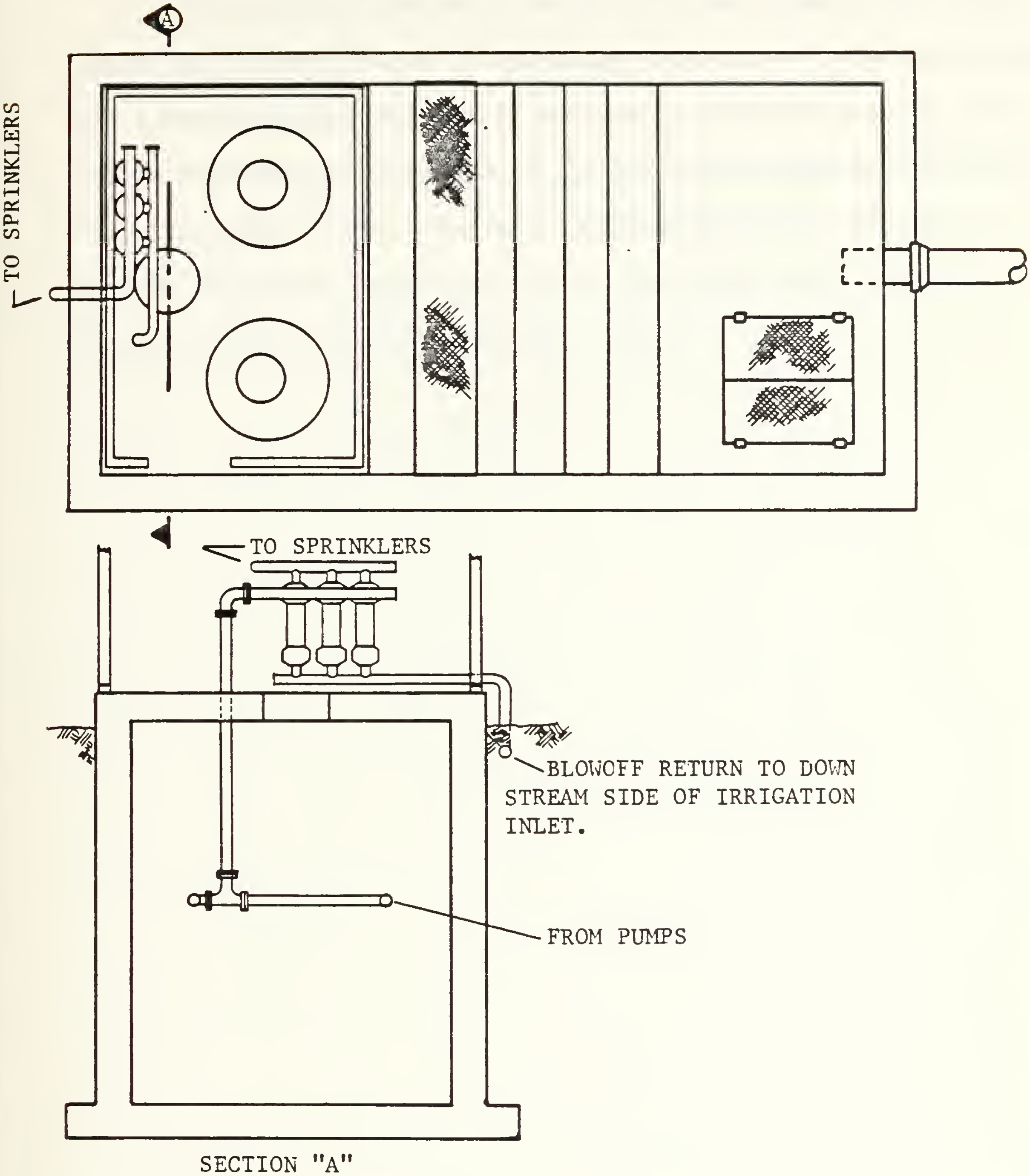

Figure 6. MODIFIED PUMPING PLANT WITH SEPARATOR

Conclusion.

The alternate method of providing filtered Smith-Goss Ditch water by relatively simple construction alterations (retrofitting) of the existing pumping plant could make water available and ready for use in the watering of grounds in the lower north campus area of the University of Colorado. The existing pumping plant currently is plumbed to deliver irrigation water to the Newton Court Housing Complex (which includes the Day Care Center).

CHAPTER IV

MAXIMIZING UTILIZATION BY DISTRIBUTION OF SMITH-GOSS WATER

Introduction

With the modifications to the existing Newton Court pumping facility as discussed earlier, that facility is capable of providing an output of 200 gpm at a total head of 140 feet (or 150 gpm at 180+ feet) on a continual, around- the-clock basis. The current watering schedule of the Newton Court complex grounds indicate that two 14-hour watering cycles occur each week, a total of 28 hours operating time.[7] If the alterations described earlier were made to the pumping facility to allow ditch water usage, the pumping facility would only be functioning a maximum of 28 hours out of a 168-hour week. It is assumed that the Newton Court pumping facility is capable of pumping an additional 140 hours a week.

In Chapter II, Table III identified that in the lower north campus area there were a total of 19.57 acres of land requiring irrigation and of that, 13.93 acres currently being sprinkled with potable (domestic) water, and of that 13.93 acres, 9.85 acres are in the Newton Court complex. The difference of 4.08 acres could be irrigated with ditch water if water could be delivered to the existing sprinkler system. Table III went on to identify 5.64 acres of land being irrigated by ditch water using flooding practice.

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[7]Interview with Pete Devani, Housing Grounds Maintenance Director University of Colorado on 29 June 1981.

There is a total of 9.72 additional acres which could utilize Smith-Goss water if there was a means of delivering that water to existing sprinkler systems in Athens, Faculty/Staff and Marine courts or delivering to an entirely new sprinkler system in the Athletic Practice Field.

The results of an examination of weekly watering schedules of each of those areas currently being sprinkled are reflected in Table XI. The total hours indicated for a watering is an accumulation of time for each lateral operation in a complex. There are numerous laterals which could be operated at the same time and those being a function of volume and pressure of water available; however, for a worst case situation the accumulation of individual times with no concurrency will be considered herein. Including Newton Court sprinkling time, there are an accumulated 84 hours per week of time utilized in watering grounds currently under sprinklers. Of the 168 hours available weekly for watering there is a potential of 84 hours (or one-half the available time) that could be utilized for watering grounds with existing sprinklers. That would allow the remaining 84 hours to be utilized in irrigating the Athletic Practice Field and for maintenance and repairs.

TABLE XI

SUMMARY OF WEEKLY SPRINKLING SCHEDULES

HOUSING AREA	HOURS/WATER	HOURS/WEEK
Athens Court	18	36
Faculty/Staff	4	8
Marine Court	6	12
Newton Court	14	28
	42	84

The present pumping facility located at the Newton Court housing complex could, if modified, provide adequate water to each of the existing or potential sprinkler systems in the lower north campus area. The remaining of this chapter will be dedicated to consideration of: (1) Athletic Practice Field Sprinkler System, (2) Delivery System, and (3) New Tie-ins to Existing Sprinkler Systems.

Athletic Practice Field

The Athletic Practice Field is located just west of the Newton Court housing complex, see Figure 7, and is immediately adjacent to the Newton Court pumping facility. The Athletic Practice Field is utilized by University athletic department as a practice field for football and other field sports. The practice field is 5.64 acres in area and consists of three-full football fields side by side.

The Athletic Practice Field is lawn turf which is flood-irrigated by means of a ditch system with field turnout boxes. Irrigation consists of diverting the ditch water out of a particular

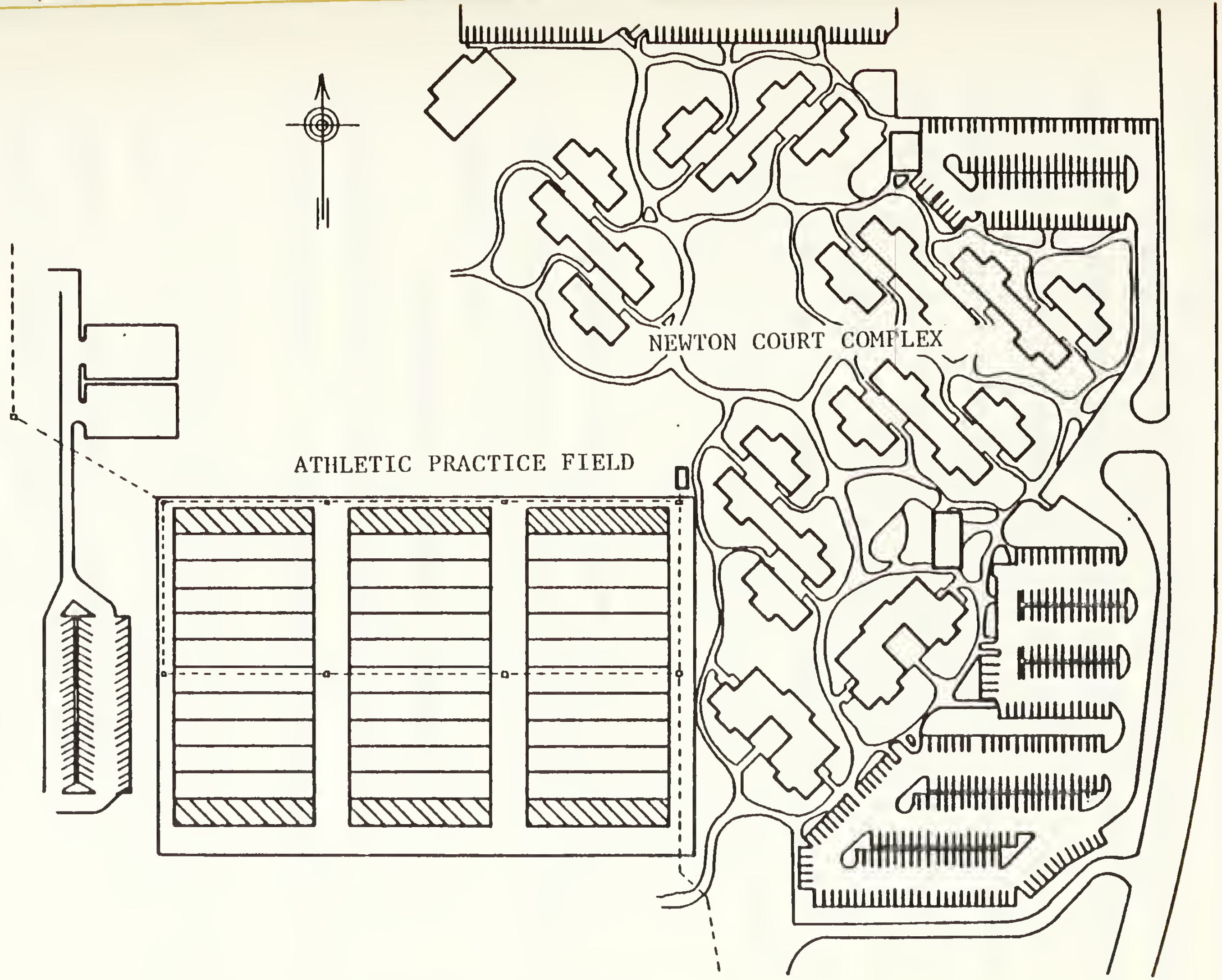

Figure 7. ATHLETIC PRACTICE FIELD

turnout box and allowed to flood over the surface. Surface distribution is occasionally assisted by the use of 6-inch diameter, collapsible rubber hoses to assure proper and timely coverage.

The irrigation of the Athletic Practice Field usually takes two 8-hour days once every ten days. This operation requires one attendant during the irrigation time. As pointed out earlier, this schedule is not a firm schedule and more often than not this scheduled is varied with longer intervals between waterings.

The Athletic Practice Field's location adjacent to the Newton Court pumping facility and its large land area makes it a prime candidate for inclusion among potential areas to be serviced by the pumping facility.

Restraints. Before the best means of irrigating the practice field can be determined a look at the operational and physical restraints must be taken.

1. The University athletic department currently restricts the watering of the practice field because of labor costs associated with the irrigation. A new system must be relatively labor free.

2. In examining the uses of the field, the most apparent restraint is that athletes are continually working out and practicing a sprinkler system could not restrict those activities nor contribute to possible physical injury to the athlete.

3) One of the most recent and possibly the most difficult or complicating restraints is the consideration of utilizing the

practice field for spill over parking for activities in the University stadium. The irrigation system could not restrict the parking and would have to be damage-proof from traffic.

Overcoming Restraints. The best way of limiting labor cost associated with irrigating the practice field would be to use an automated sprinkler system. This would, of course, require a high initial installation cost but would require minor operational and maintenance costs. Sprinkler systems could consist of underground piping with fixed sprinkler head or could be surface layed or a side role type of system. The latter would require higher operating labor costs with lower installation costs than the former.

Most fixed underground sprinkler systems could contribute to injury of an athlete, however, recently one manufacturer has developed a sprinkler head that when not being utilized retracts to a $^{1}/2$ to 1 inch depth below the ground surface. Upon pressurizing the sprinkler system the head then pops up to approximately 4 inches above the ground surface, allowing adequate clearance for watering. This system is currently being used in many major professional and collegiate football and baseball stadiums and has proven to be both nonrestrictive and safe to the athlete.

The retractable sprinkler head system under dry lawn conditions can be safely utilized in conjunction with vehicular parking and traffic; however, if moist ground conditions exist vehicles would sink into the ground possibly damaging the retractable sprinkler heads. This could be overcome by placing temporary

protective plates over each individual sprinkler head when the practice field as is used as a parking lot. Surface layed (or side roll systems) could be removed from the area prior to parking and would allow nonrestricted parking and traffic flow.

Selecting a system. Reviewing the restraints and examining the way to overcome each restraint, indicates that there is no clearly superior alternative. In choosing between an underground retractable head system or the surface portable system both have advantages and disadvantages. The underground retractable head system requires less operating costs. Both systems would give the athletes unrestricted safe playing conditions. Portable sprinklers on wheels have a tendency to create depressions at wheel locations which could cause an unsafe condition. If the practice field is used for spill-over parking, the portable system would be less restrictive to parking and traffic than the underground retractable head system.

In selecting one system over the other, it was decided to design an underground retractable head system because the parking option may not come about and the selected system is the least labor intensive of the alternatives.

Automated underground retractable head system. The Athletic Practice Field has a seasonal supplemental moisture requirement of 34 inches and to make that volume available 46 inches must be applied. From Figure 3 the peak daily water requirement is in July with a peak requirement of 0.319 inches/day or 2.23 inches/week; therefore, any sprinkler system must provide at least that volume. Applying the 75% irrigation efficiency factor, it is found that a total application of

2.97 inches/week would be required. Because of the heavy practice demands that are put on the field, it is deemed necessary to restrict watering to a once-a-week cycle. Using the 3-inch per week requirement and of watering only once a week assisted in the selecting of a particular sprinkler head. Considering the overall size of the area, the number of heads and the possibility of the proposed parking scheme resulted in a 70-foot spacing that would be a convenient and desirable. To determine the sprinkler design diameter at 70-foot spacing, divide the 70-foot by 60% of desired overlap, yielding 120 diameter.[15] Knowing the output required and the sprinkler diameter a particular sprinkler head and nozzle size can easily be selected. A sprinkler head with a 5/16-inch nozzle working at 60 psi with an output rate of 22.5 gpm, 120 diameter and precipitation rate of 0.70 inches/hour was selected.

Once spacing is determined piping layout is the next item for design. With a normal pump output of 150 gpm and a unit sprinkler head output of 22.5 gpm the maximum number of sprinklers per lateral would be six. A scheme for connecting up to six sprinklers into a lateral systems was determined by examining numerous layout combinations while at the same time increasing efficiency and decreasing losses. Figure 8 reflects an efficient layout with twelve laterals being fed by two sub-mains.

Pipe sizes were then determined by identifying working pressure and volume at the last sprinkler and working back through the

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[15]Buckner, "Sprinkler Irrigation Manual".

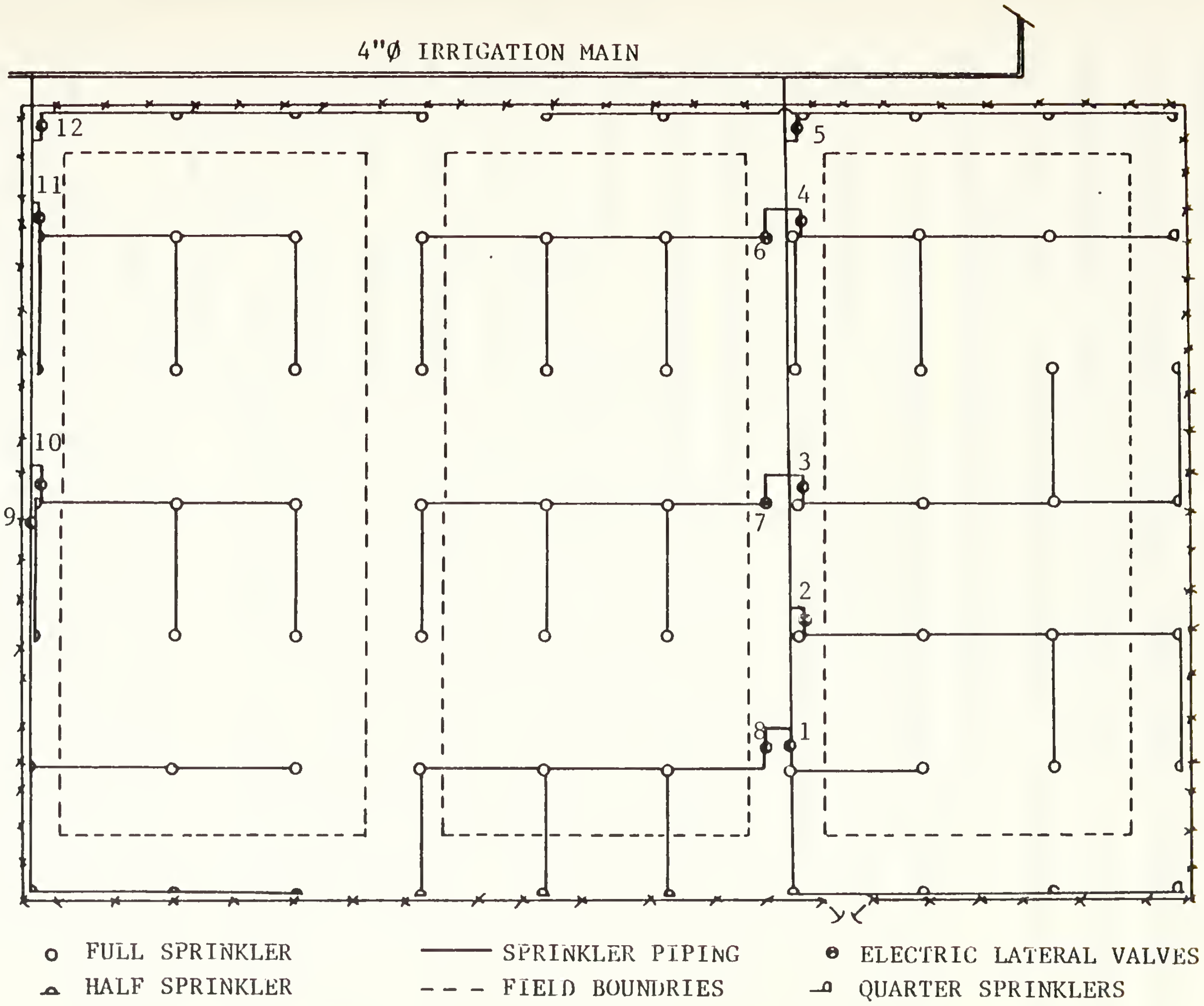

Figure 8. ATHLETIC PRACTICE FIELD SPRINKLER SYSTEM

lateral picking up new volumes at each sprinkler location while maintaining noncritical flows. Pipe sizes are indicated on Figure 8. Following pipe size determination each lateral was defined as to pressure loss Each lateral was controlled by an electric gate valve. The valves are located at the head of each lateral and attached to a sub-main which in turn runs to a point of connect at a 4-inch main. Valves are placed at this location to assist in isolating the lateral from the main so that repairs can be made more easily.

The resultant design indicates the highest pressure loss is 5.77 psi in lateral P-8. With pressure loss in the sub-main feeding P-8 being approximately 3.90 psi, the pressure required at the point-of-contact gate valve would be 69.67 psi (sum of 60 psi for the required sprinkler pressure plus 5.77 psi lateral loss, plus 3.90 psi sub-main loss). Pressure losses from the pump to the sub-main point-of-contract would be 5.60 psi (sum of 5.00 psi loss in the commercial separator plus 0.60 psi loss in the pipe and fittings). The pump at an output of 135 gpm (6 x 22.5 gpm) has a total head of 184 feet or 79.7 psi. Taking the loss in the separator, piping and fittings results in a flow of 135 gpm at the point of contact with a pressure of 74.1 psi. That pressure is adequate to support the lateral requirement of 69.7 psi.

The sprinkler design as shown in Figure 8 is a workable design which can give a 1.25 inch irrigation rate per hour. (The 1.25 inch is more than the 0.70 inch mentioned earlier due to overlapping.) Thus, in scheduling each lateral to operate for a two-hour period the maximum 3.00 inch/week application requirement

will be attained. The entire practice field can be irrigated in a 24-hour period.

Distribution System

Since the pumping plant has adequate capabilities of providing additional water, a means of conveying that water to desired locations must be examined. Figure 9 identifies the location of the pumping facility in relation to the various housing complexes and the Athletic Practice Field. The existing pumping facility delivers water to the Newton Court facilities and to the Athletic Practice Field through a 4-inch connect at the pumping plant. The remaining areas requiring ditch water delivery are the Athens, Marine, and Faculty/Staff courts' sprinkler irrigation systems.

Existing sprinkler systems. An examination of the existing sprinkler systems at the three discussed housing complexes reveals a total of 39 different laterals (Athens, 21 each; Faculty/Staff, 6 each; and Marine, 12 each). A lateral is defined as a set of sprinklers on a continuous piping run operated by one valve. There are existing point-of-contacts to the domestic water mains that service both the domestic use and irrigation laterals. There are three points-of-contact at Athens Court, one at Faculty Staff, and four at Marine Court. Figure 9 shows the approximate location of each of these points-of-contact and they are numbered consecutively clockwise from the southeast corner of Athens Court. Table XII is a summary of those points-of-contact (POC) and the laterals serviced by each POC.

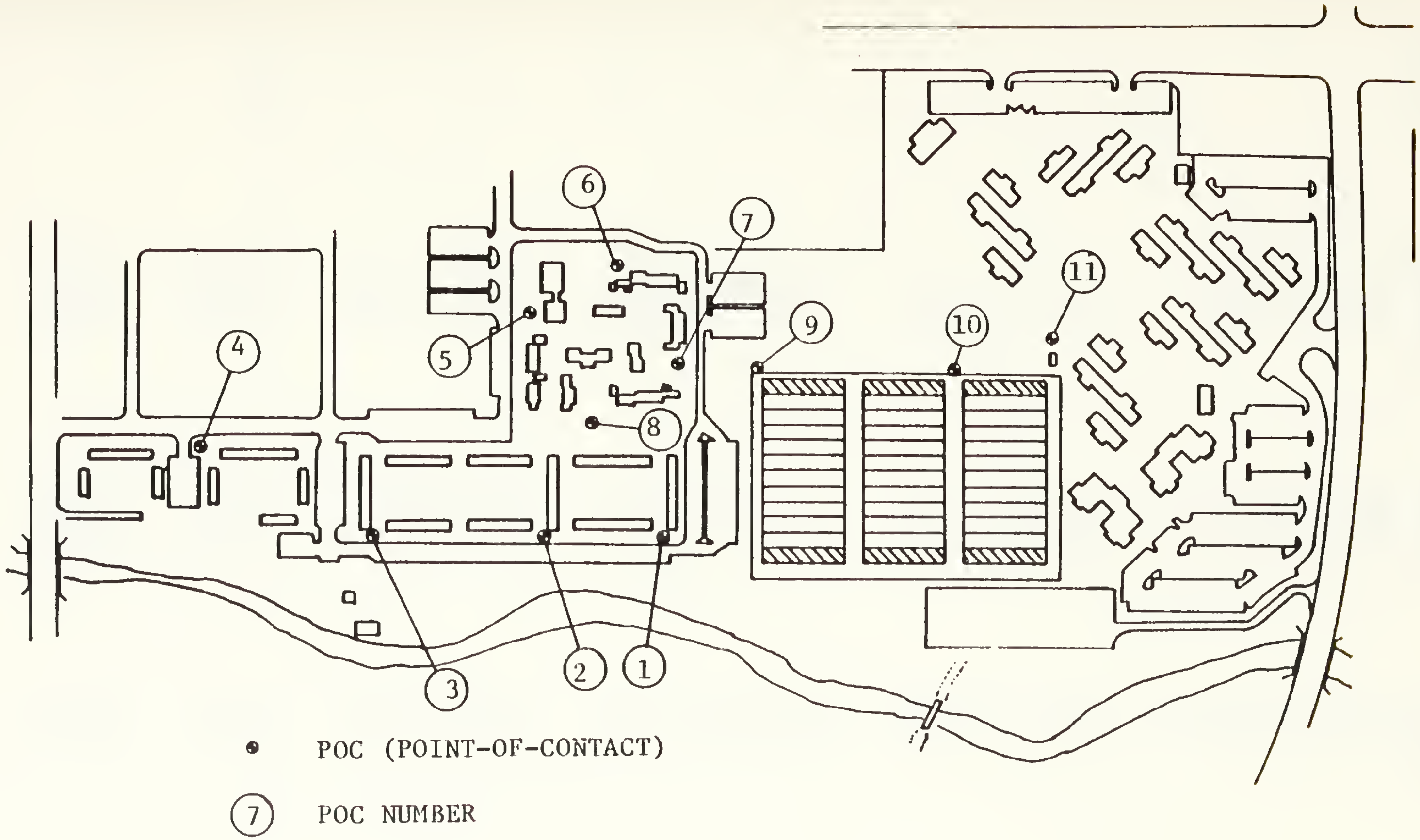

Figure 9. POINT-OF-CONTACTS OF EXISTING AND NEW SPRINKLER LATERALS

TABLE XII

POINT OF CONTACT/LATERAL SUMMARY

POC #	Laterals Serviced	Output Required (Min)	Weekly Operation (Min)	Total Min. Head Required* (PSI)
1	A-1	43.1	80	47
	A-2	52.2	80	53
	A-3	49.1	80	47
	A-4	41.3	80	55
	A-5	41.3	80	55
	A-6	50.8	80	47
	A-7	96.0	240	59
2	A-8	43.1	80	47
	A-9	52.2	80	53
	A-10	49.1	80	47
	A-11	41.3	80	55
	A-12	41.3	80	55
	A-13	50.8	80	47
	A-14	96.0	240	59
3	A-15	43.1	80	47
	A-16	52.2	80	53
	A-17	49.1	80	47
	A-18	41.3	80	55
	A-19	41.3	80	55
	A-20	50.8	80	47
	A-21	96.0	240	59
4	F-1	63.6	80	53
	F-2	137.5	80	53
	F-3	75.8	80	54
	F-4	96.6	80	55
	F-5	77.6	80	51
	F-6	70.6	80	53
5	M-10	57.9	60	46
	M-11	49.8	60	45
	M-12	51.7	60	54
6	M-3	48.4	60	52
	M-4	44.1	60	47
	M-9	58.2	60	53

"Table 3 (continued)"

7	M-1	60.7	60	55
	M-2	51.3	60	49
8	M-5	74.3	60	50
	M-6	81.6	60	49
	M-7	79.9	60	46
	M-8	74.8	60	43

Locating the main. An examination of the locations of the points-of-contact indicates that there would be no simple or direct distribution system to each POC. Figure 10 indicates one possible distribution system from the Newton Court pumping facility to all points-of-contact. The distribution system is so placed as to minimize sub-main lengths (sub-mains are feeds from the main to the point-of-contact to new or existing sprinkler laterals), while minimizing difficult and expensive construction areas. The distribution further provides a loop system which will allow isolation of areas for making repairs while still serving other areas.

Sizing the main. The data presented in Table XII indicates that the maximum flow required at any one lateral is 137 gpm at lateral F-2 which so happens to be one of the farthest from the pumping facility. If the distribution system is designed to carry adequate water to that location, then the system would be adequate

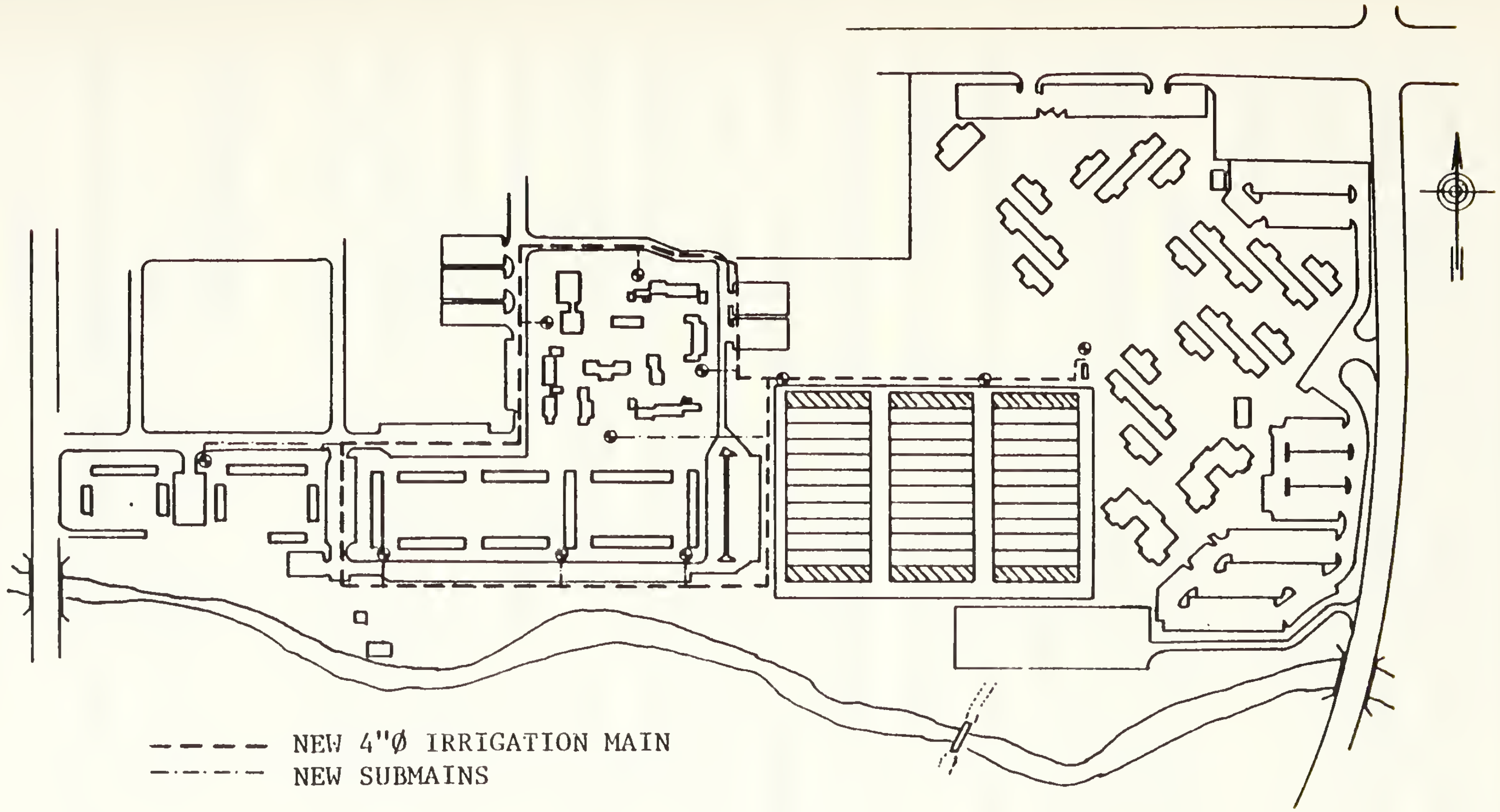

Figure 10. LOCATING THE DISTRIBUTION MAIN

for all other laterals. The total head available at the pump at an output of 137 gpm is approximately 180 feet or 78 psi. Lateral F-2 requires an operating pressure of 53 psi, thus the maximum allowable pressure drop is 25 psi. As pointed out earlier there is a 5 psi pressure drop through the commercial separator at the pumping facility, thus only 20 psi is available for losses in the distribution system.

There is no substantial elevation differential in the area. Applying the pipe-friction equation $h_L = f \frac{L}{D} \frac{V^2}{2g}$ and "It is generally conceded that, for pipes of length greater than 1,000 diameters, the error incurred by neglecting minor losses is less than that inherent in selecting a value of f, a friction loss in the proposed distribution system can be determined.[16] The longest length of the main is 2,325 feet (well beyond a 1,000 diameter). Assuming first a 3-inch diameter PVC pipe and using the pipe-friction equation with a desired discharge of 137 gpm, a 36.3 psi head lost was determined. That exceeds the allowable 20 psi. A new assumed pipe diameter of 4-inch was tried and using the same flow, a 10.5 psi pressure drop was determined. That is half the allowable and the 4" PVC piping was considered adequate for the distribution main to service the irrigation sprinkler systems in the lower north campus area.

Alternate System.

Is there an option to provide a distribution system from the Newton Court pumping facility such as another pumping station for

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[16] Daugherty, R. L. and Franzini, J. B., Fluid Mechanics with Engineering Application, sixth edition, 1965 p. 233..

ditch water or even possibly converting ditch right to well rights and pumping from an irrigation well?

Pumping/filtration plant number 2. Figure 2 shows the location of the Smith-Goss ditch as it passes through the lower north campus area. It can be concluded that there is no central pumping location which would eliminate the distribution system as designed.

Irrigation well. Reviewing the existing points-of-contact identified in Figure 9 does not yield any particular location for a well which would eliminate a distribution system similar to that already designed to deliver ditch water from the Newton Court pumping facility. Also, past test wells in the lower north campus have yielded a transmissibility of approximately 2,650 gallons per day per foot in an average 20-foot thick acquifer.[17] This would yield a pumping rate of approximately 37 gpm. For such a well to provide adequate water for the required pumping of 137 gpm a storage reservoirs would be required. The ability to acquire a well permit at this location is doubtful.

Summation. It is felt that neither a second pumping/filtration plant nor the irrigation well would relieve the requirement for a distribution system as previously designed. It is also obvious that if either option was considered, there would be addition construction cost incurred beyond that of the costs of the distribution system.

The distribution system serving from the Newton Court pumping

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[17]William B. McDowell & Associates letter of 11 September 1972 to McCall-Ellingson Consulting Engineers.

facility appears to be the simpliest and most practicable means by distributing irrigation water to the sprinkler systems at Athens, Faculty/Staff, and Marine courts.

<u>Connecting New Irrigation Main to Existing Sprinkler Laterals.</u>

Before that distribtion system can be utilized, the existing systems must required to be disconnected from the domestic water supply and connected to the new ditch water supply mains at the eight points of contact mentioned earlier. Figures 11 (a) through (e) are piping schematics which reflect the new tie-in piping and the domestic water piping to be disconnected on all eight points-of-contact.

<u>Summary.</u>

A design has been completed for irrigating the Athletic Practice Field by means of an automatic sprinkler system. That design has provided a labor-saving, athlete-safe system which will allow use of the practice field as an overflow parking area. The construction of this system could save as much as 22 ac-ft of ditch water per year.

The distribution system would carry irrigation water to all existing sprinkler systems in the lower north campus area and would convert each of these systems from domestic water to ditch water. The distribution system would use 15.64 ac-ft/year to water the grounds at the Athens, Faculty/Staff, and Marine Courts housing complexes.

Coupling the retrofitting of the pumping plant with the existing distribution system a new athletic field sprinkler system, it is possible to use the 65 ac-ft/year of Smith-Goss ditch water in

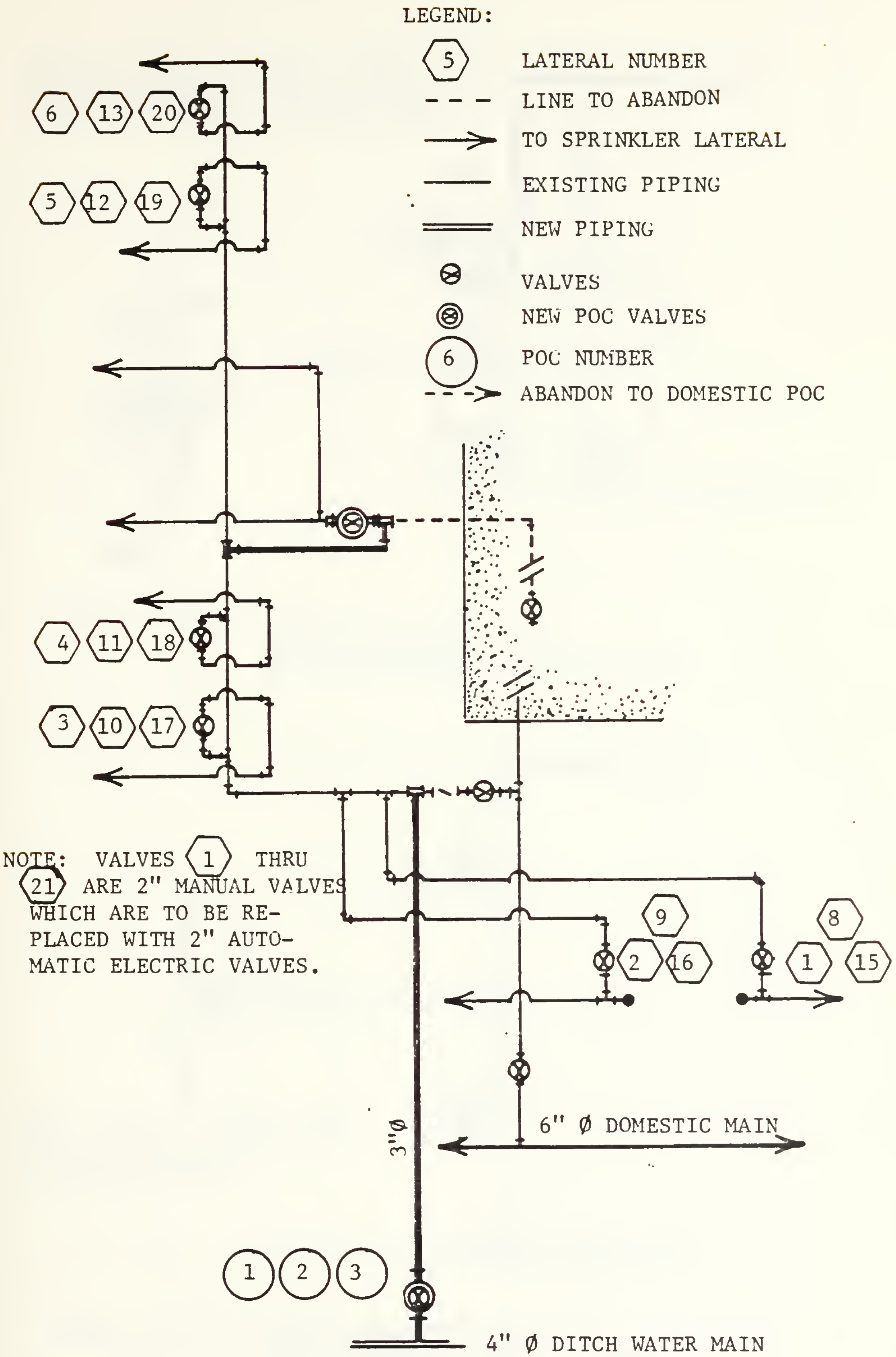


Figure 11(a). POINT-OF-CONTACTS NO. 1 THRU 3
PIPING SCHMATIC AT ATHENS COURT

NOTE: VALVES 1 THRU 6 ARE
2" MANUAL VALVES TO BE REPLACED
WITH 2" AUTOMATIC ELECTRIC VALVES.

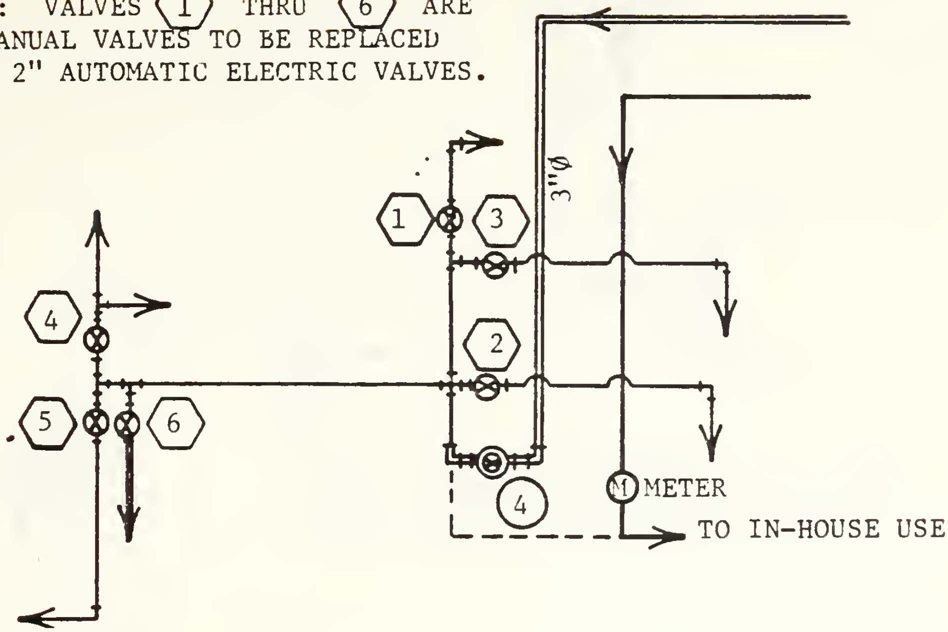
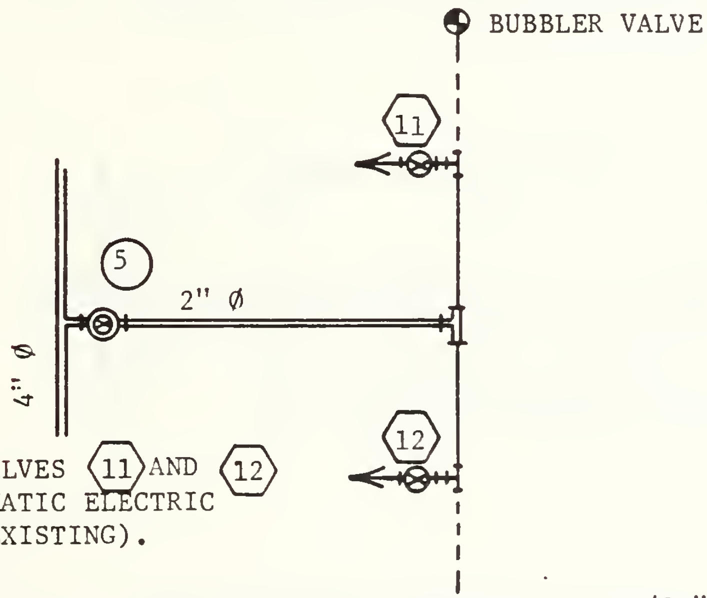


Figure 11(b). POINT-OF-CONTACT NO. 4
PIPING SCHMATIC AT FACULTY/STAFF



NOTE: VALVES 11 AND 12
ARE AUTOMATIC ELECTRIC
VALVES (EXISTING).

Figure 11(c). POINT-OF-CONTACT NO. 5
PIPING SCHMATIC, WEST SIDE MARINE COURT

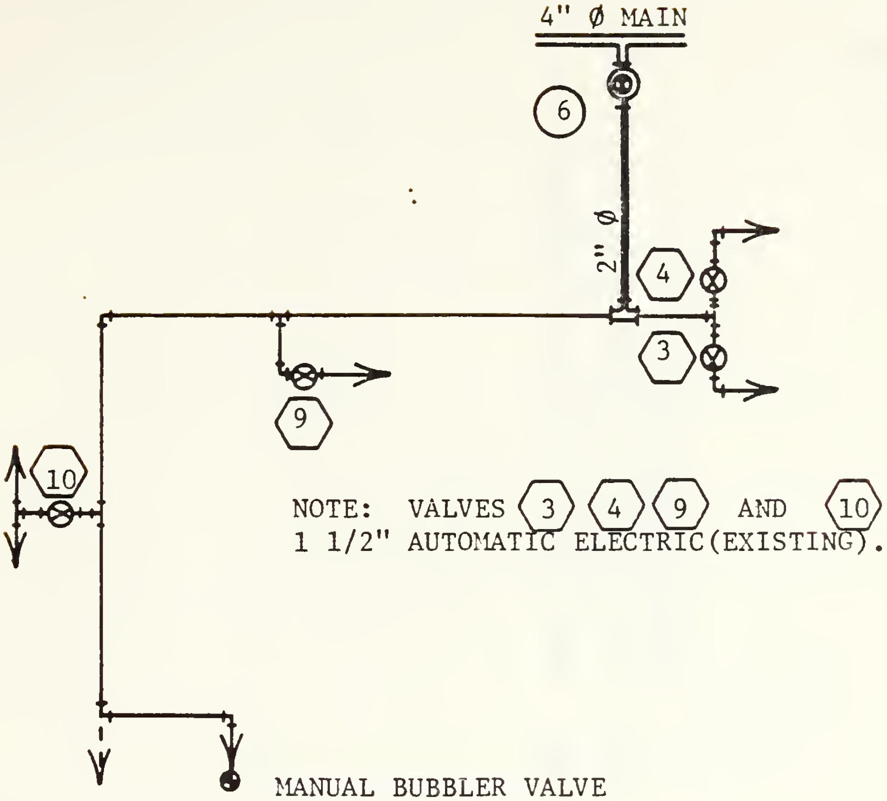


Figure 11(d). POINT-OF-CONTACT NO. 6
PIPING SCHMATIC, NORTH SIDE MARINE COURT

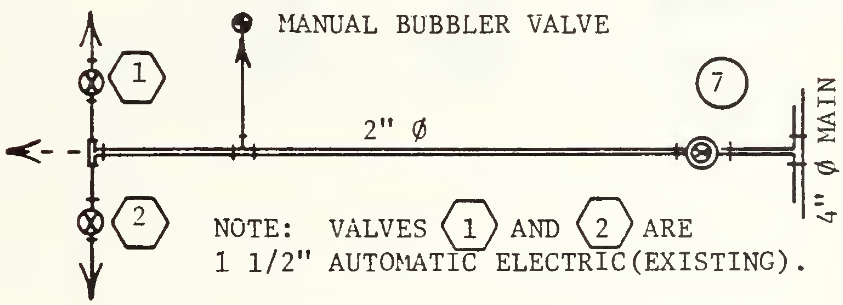


Figure 11(e). POINT-OF-CONTACT NO. 7
PIPING SCHMATIC, EAST SIDE MARINE COURT

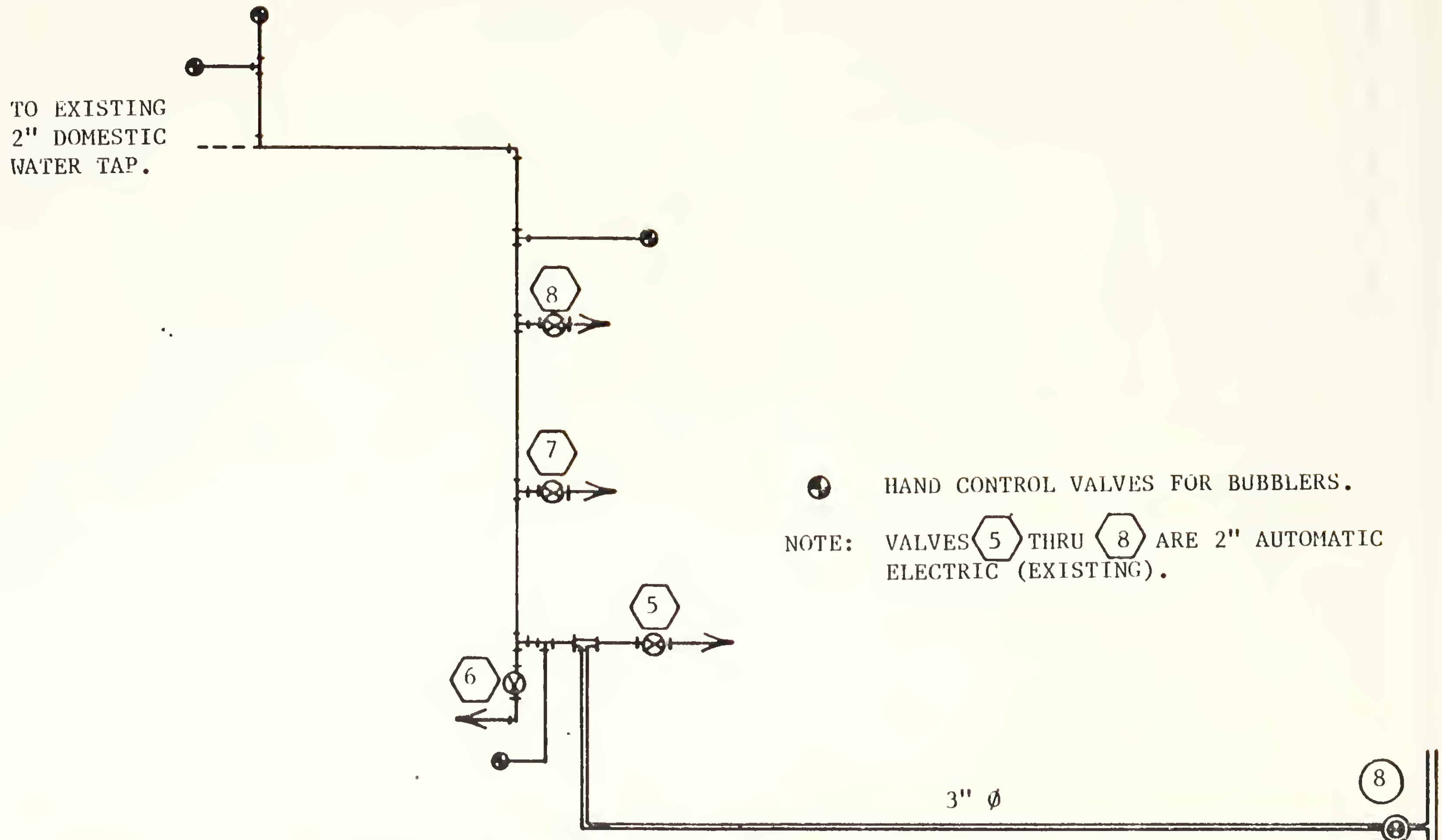


Figure 11(f). POINT-OF-CONTACT NO. 8
PIPING SCHMATIC, SOUTHEAST SIDE MARINE COURT

the lower north campus area. This 65 ac-ft is still short of utilizing the 990 ac-ft available; however, it would definitely be an increase over current usage.

CHAPTER V

DETERMINATION BY COST ANALYSIS

Introduction

It has been discussed that the University currently uses 44.02 ac-ft of domestic water annually in the irrigation of lawn areas in Athens, Faculty/Staff, Marine, and Newton courts. There are also 22 ac-ft of Smith-Goss ditch water used in the irrigation of the Athletic Practice Field. A total of 66 ac-ft are required annually to irrigate all the available grounds in the lower north campus area.

The University has recommended 2.75 cfs flow in the Smith-Goss Ditch Company. That flow rate could yield yearly 990 ac-ft. The University has, apparently, abandoned 968 ac-ft (990 - 22); however, with immediate effort could possibly utilize an additional 44 ac-ft of ditch water with no abandonment action filed by the courts. To accomplish the utilization of that 44 ac-ft per year, would require the retrofitting of the Newton Court pumping facility. Once the pumping facility has been modified, irrigation water could then be delivered to the Newton Court housing complex's 5.64 acres (27.67 ac-ft) of lawn without further modification. To utilize the remaining 16.35 ac-ft requires the construction of a piping conveyance system to eight different points of contact throughout the remaining housing complexes.

The designs for retrofitting the pumping plant, delivering the ditch water and the tie-ins into the existing system have been

discussed earlier in detail. Those designs indicate that with no major design or construction difficulties the systems can be constructed to allow the utilization of the 44 ac-ft of ditch water.

The question must be examined as to whether it is financially feasible to design and construct the systems required to utilize those additional 44 ac-ft of water. The remaining of this chapter will be devoted to analyzing costs to determine the practicability of the retrofitting, distribution and tie-ins.

Cost Analysis

Examining the entire system it is obvious that the utilization of ditch water can be increased through increments. The first increment would be the retrofitting of the Newton Court pumping facility. Once that modification is made 27.67 ac-ft per year can be utilized without additional cost. The second increment would be to deliver the water to the other housing complexes and to tie-in existing sprinkler systems. This would result in use of the remaining 16.35 ac-ft. The final increment would be to provide a new sprinkler system for the Athletic Practice Field which would use an additional 22 ac-ft/year.

Parameters. The forthcoming analysis is based on present worth costs per Kgal utilizing either domestic or ditch water. The benefits from using either domestic water or ditch water would be the same--a well irrigated, lawn for which no dollar value can be assigned.

The existing sprinkler systems were installed at different times over the last twenty years. For this study the condition, repair, and replacement of each system will not be considered because those costs will be incurred no matter which water is being used.

The irrigation ditch water will be assessed an initial market value of zero dollars because it has legally been abandoned. It has no market value in that it has not been applied to beneficial use and there has been no definable consumptive use. (It should be noted that the water applied to the athletic field is an exception.)

The project will be assumed to have a life of 20 years. This based mainly on the fact that pumps have a twenty-year life. As noted earlier, the various sprinklers are of different ages and as such will vary as to expected life periods. The discount rate is 8%.

Domestic water. The unit cost of domestic water will be considered as a fixed price even though earlier it was shown that past prices have averaged 10% per year increase. The present cost of water is $0.4697/Kgal.

Newton Court. By retrofitting the Newton Court pumping facility at a cost of $9,500 some 9.85 acres can be irrigated by applying approximately 27.67 ac-ft yearly (9.016 Kgal). That same volume of water is currently being applied by a domestic water system. The comparison of present worth costs are identified in Table XIII.

TABLE XIII

NEWTON COURT PRESENT WORTH WATER COSTS COMPARISON

	Domestic Water	Ditch Water
Initial Investment	0	-$9,500.00
Water Costs ($/yr)	-$4,235.00	- (810.00)*
Pumping Cost ($/yr)	0	- 367.00
Maintenance ($/yr)	0	0
Operator Costs ($/yr)	0	0
Depreciation ($/yr)	0	0
Present Worth Total Costs	-$47,677.00	-$13,632.00
Present Worth Cost/Kgal	-$ 0.2644	-$ 0.0756

*The $810.00 is ditch assessment costs continually incurred and not used in the comparative analysis.

The results indicate that by using domestic water the University an additional $0.1888 per gallon for water used over the next twenty years, yielding a total present worth difference of $34,045.

<u>Housing complexes irrigation</u>. Following the retrofitting of the Newton Court pumping facility and utilization of ditch water at the Newton Court complex, the system can be expanded to distribute ditch water to the entire lower north campus area by a 4" diameter system with tie-ins into the existing sprinkler systems in Athens, Faculty/Staff, and Marine courts. The costs of delivering and utilizing ditch water for irrigation in all housing complexes are compared to those of domestic watering in Table XIV.

TABLE XIV

HOUSING COMPLEXES, PRESENT WORTH COST COMPARISON

	Domestic Water	Ditch Water
Initial Investment	0	-$64,356.00
Water Costs ($/yr)	-$ 6,737.00	- (810.00)*
Pumping Cost ($/yr)	0	- 1,100.00
Maintenance ($/yr)	0	0
Operator Costs ($/yr)	- 4,160	0
Depreciation ($/yr)	0	0
Present Worth Total Costs	-$122,676.00	-$71,497.00
Present Worth Cost/Kgal	-$ 0.4276	-$ 0.2492

*The $810.00 is ditch assessment costs continually incurred and not used in the comparative analysis.

The results indicate that the University could save a total of $51,179 over the next twenty years by utilizing ditch water by retrofitting the Newton Court pumping facility and distributing ditch water throughout the housing complexes. That is equivalent to a $0.1784/Kgal additional cost for water utilized over the twenty years if the University continues to apply domestic water for irrigation purposes.

Lower north campus area. The inclusion of the practice field into the entire distribution, does not allow for complete cost comparison because domestic water is not being applied there currently. A unit price for delivering irrigation water to every location possible in the lower north campus area and incorporating a new sprinkler system in the practice field is presented in Table XV.

TABLE XV

UNIT PRESENT WORTH COST FOR WATER LOWER NORTH CAMPUS AREA

	Ditch Water
Initial Investment	-$90,219.00
Water Costs ($/yr)	(810.00)*
Pumping Cost ($/yr)	- 1,415.00)
Maintenance ($/yr)	0
Operator Costs ($/yr)	+ 1,440.00
Depreciation ($/yr)	0
Present Worth Total Costs	-$90,219.00
Present Worth Cost/Kgal	-$ 0.2098

*The $810.00 is ditch assessment costs continually incurred and not used in the comparative analysis.

The present worth $0.2098/Kgal for pumping ditch water throughout the lower north campus area is considerably less than the present worth $0.4276 being charged for domestic water.

Comparing with resale of ditch water. The Smith-Goss ditch water appropriated to the University is probably legally abandoned and as such has no current resale value; however, if the University began to applying the diverted water and over the next years establish a definite use, then the water would have a resale value. Sale of appropriated water is typically based on the consumptive use of the applied water and the consumptive use volumes in the lower north campus area are shown in Table XVI.

TABLE XVI

CONSUMPTIVE USE/MARKET VALUE

	Consumptive Use (Ac-Ft)	Market Value ($)
Athens Court	4.96	14,880.00
Faculty/Staff	2.87	8,610.00
Marine Court	3.77	11,310.00
Newton Court	28.00	84,000.00
TOTAL:	29.00	118,800.00

The market value of ditch water is a function of numerous factors; i.e. seniority and seasonal availability. The current value of the Smith-Goss ditch water, because of its high seniority and the long watering season, is approximately $3,000 per acre-foot of consumptive use.[18] Table XVI identifies the sale value of the consumptive use of water on the grounds being irrigated and that indicates in current dollars what the market would price would be. Utilizing the ditch water would actually be developing an investment which would yield $118,800 for the University.

Table XVII identifies present worth comparison of the domestic water and ditch water costs using a salvage value.

[18]Interviews with David L. Harrison of Moses, W. Hemyer, Harrison and Woodruff, P. C. Law Offices, Boulder, Colorado of 18 December 1981 and 22 July 1983.

TABLE XVII

PRESENT WORTH COST COMPARISON INCLUDING SALVAGE VALUE

Area	Total Costs $			$ Cost/Kgal		
	Domestic	Ditch	Difference	Domestic	Ditch	Difference
Newton Court	-47,677	+70,368	118,045	-0.2644	+0.3902	0.6546
All Housing Complexes	-122,676	+42,038	164,714	-0.4276	+0.1465	0.5741
All Areas	-122,676	28,581	151,257	-0.4276	+0.0662	0.4938

Conclusions

The results of this study indicate that the University could save $118,045 over the next twenty years by retrofitting the Newton Court pumping facility and utilizing Smith-Goss ditch water. Those savings are accomplished with a $9,500 investment. Further, by installing the distribution system throughout the lower north campus area and utilizing ditch water rather than domestic water would save the University a total of $164,714 at a cost of $64,356 on a benefit/cost ratio of 2.56.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This thesis has described the existing irrigation uses of domestic and ditch waters in the lower north campus area and identified the legal status of the Smith-Goss Ditch water as it pertains to its nonuse. A review of the inoperable Newton Court pumping facility yielded a proposal for retrofitting which would allow use of ditch water in the Newton Court Complex. Coupling the retrofitting with a design of a distribution system, it was found that ditch water could be delivered to each housing complex and through a tie-in system with automatic, time controlled valving, all areas could be watered efficiently.

Water Usage

There are 19.57 acres of grounds in the lower north campus area which require irrigation, 5.64 acres are irrigated by flooding with ditch water, while the remaining 13.93 acres are irrigated through sprinkler systems utilizing domestic water purchased from the City of Boulder.

Ditch water. The Smith-Goss Ditch Company has a recommended appropriation of cfs/yr and of that the University owns 55% of the shares, or 2.75 cfs which yields 990.0 ac-ft/yr. The University only irrigates the Athletic Practice Field utilizes approximately

21 ac-ft/yr. The University has apparently abandoned all the appropriated Smith-Goss ditch water except the 21 ac-ft/yr currently being utilized; however, the water courts have not yet recognized the abandonment. It is considered highly possible that the University could commence utilizing the water without any action being taken.

Domestic water. The domestic water applied for irrigation is not directly measurable in that both lawn areas and in-house usages are meter jointly. Three different methods of determining the volume of water utilized for irrigation were considered: (1) winter usage was equated to in-house per unit usage and applied to the summer occupancy rates to obtain a total in-house summer use. The difference between total metered and calculated in-house summer use yields the meter applied for irrigation, (2) review of sprinkler design outputs and watering schedules yielded an estimate of the total applied water, and (3) consumptive use by lawns was determined and applying an irrigation efficiency yielded a total irrigation water required. Averaging of the three methods yielded quantities sufficiently accurate to utilize in this analysis. It was found that a total of 44.02 ac-ft (14,344 K/gal) of domestic water was applied each year for lawn irrigation.

Utilizing Smith-Goss Ditch Water.

Recognizing that the University had a total of 990 ac-ft/yr of ditch water available and of that only 21 ac-ft were being utilized prompted the request for this thesis project. An additional 44 ac-ft/yr of the ditch water can be applied to beneficial use by

simply replacing domestic water with ditch water. The usage of ditch water requires retrofitting existing systems and distributing that water.

Initial Cost Analysis

A present worth cost comparison of utilizing domestic water versus ditch water was conducted. Initially, the analysis was done figuring a zero dollar worth of the ditch water because it was assumed that the water had no market value in that it could not be sold.

Newton court retrofitting. It was determined through the analysis that over a twenty-year period, the total present worth cost of utilizing domestic water on the Newton Court lawn area was $47,677 or a cost $0.2644/kgal of applied water. Utilizing ditch water would cost the University $13,632 or $0.0756/kgal. A substantial savings of $34,045 could be achieved by utilizing ditch water on the Newton Court grounds.

Housing Complexes. In comparing costs for watering all lawns for the housing complexes in the lower north campus area, it was found that the total present worth cost for domestic water is $122,676 or a unit cost of $0.4276/kgal, while for ditch water the total cost is $71,497 or unit cost of 0.2492/kgal. The total savings in using ditch water would be $51,179.

Final Cost Analysis.

If the University began utilizing the Smith-Goss ditch water at the end of the analysis period (assuming no abandonment claim was

filed), the ditch water appropriation would be valid and as such the consumptive use volume being utilized would be marketable. The present worth value of ditch water with senior priority rights of the Smith-Goss Ditch is $3,000/ac-ft consumptive use. This value was included in the cost comparison analysis as salvage value. Using all costs as before adding a salvage value of $84,000 (the present worth ditch water market value for 28.00 ac-ft), it was found that the present value of using domestic water would be $47,677 compared with using ditch water which would yield a net gain of $70,368. That is to say, for every thousand gallons of ditch water applied to the Newton Court grounds over the next twenty years the University would be making $0.3902. By applying ditch water, the University would save the $47,677 of costs and be making $70,368 profit that yields a total savings of $118,045. Using Smith-Goss ditch water throughout all housing complexes in the lower north campus area, would yield a net savings to the University of $164,714 over the next twenty years.

The last extra step in developing an automated sprinkler system through the entire lower north campus area would be to install a sprinkler system in the Athletic Practice Field and tie that into the distribution system being furnished water through the Newton Court pumping facility. Currently the only costs incurred are labor costs totalling approximately $1,400 a year. The total domestic water cost for watering the housing areas is $122,676 (0.4276/Kgal), while ditch watering the entire lower north campus area (housing complexes

the Athletic Practice Field) the present worth value net gain would be $28,581.00 (or $0.0662/Kgal).

Conclusion

The University has apparently abandoned 99% of the Smith-Goss ditch water it possesses; however, through retrofitting the Newton Court pumping facility, distributing ditch water to Newton Court, Athens Court, Faculty/Staff Court, and Marine Court, and by installing a sprinkler system in the Athletic Practic Field the University can regain a right for an annual consumption of 66 ac-ft of ditch water. The resultant savings to the University total $151,257 over the next twenty years.

The options presented in this thesis appear to be extremely practicable and economically feasible and should be examined in greater detail.

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APPENDIX I

DOMESTIC WATER UTILIZED FOR IRRIGATION

BY SUMMER/WINTER TECHNIQUE

Direct flow measurements were not available for measuring volume of domestic water applied for irrigation in areas serviced by the Smith-Goss Ditch. The method of determining the volume of domestic water applied for irrigation (summer/winter technique) is as follows:

Step 1. Identify the monthly volume of water applied for each housing area for each year under consideration. (Each housing area domestic water was furnished via an independent water meter, however, that meter measured in-house and irrigation quantities.) Once the monthly volume is obtained the period in which no irrigation is accomplished (November through April or December through May billings) is summarized and averaged yielding a winter monthly average of in-house use for that particular, entire housing complex. The monthly average for summer (in-house plus irrigation) was obtained by a similar procedure.

Step 2. The monthly housing complex occupancy rates were next identified. These figures were compiled so as to run parallel with the water consumed per complex. Six-month average occupancy rates were obtained for the winter period (November through April) and for summer (May through October) for each housing complex and for the years being considered.

Step 3. Taking the winter monthly average of water consumed for a particular housing unit for a given year and dividing that by the number of units occupied (occupancy rate times total number of units in a complex) yielded a volume of domestic in-house water (Kgal) utilized per household per month. Once the in-house

volume per unit is obtained, multiply that quantity by the average number of units occupied during the summer thus obtaining a total in-house volume utilized per housing complex per month.

Step 4. Knowing the monthly summer in-house use per housing complex and multiplying that by six (number of irrigation months) yielded a total domestic water utilized for in-house use during the entire irrigation season. By subtracting that total from the total metered domestic water for the same six-month period yielded a total six-month volume of water applied for irrigation. Knowing the area of grounds being water allowed the total volume of applied irrigation water to be transposed in to total inches applied per season or inches applied per month.

Example of Summer/Winter Technique:

Newton Court Housing Complex for 1980.

Step 1. Billings for thousands of gallons (Kgal):

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1907*	1351*	1356*	1285*	1876	1796	3489	4330	3663	2626	2157*	1863*

*Winter months (billing one month after consumption).

Total Winter: 1938 Kgal Average Winter/Month: 1606 Kgal

Total Summer: 18061 Kgal Average Summer/Month: 3010 Kgal

Step 2. Occupancy rates:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
98.2*	99.4*	99.8*	99.8*	99.0	96.5	87.0	86.8	98.6	99.6	100.0*	97.4*

*Winter months

Monthly average (winter): 99.1%

Monthly Average (Summer): 94.6%

Step 3.

$$\frac{\text{1606 Kgal (average winter monthly volume)}}{\text{99.1\% (Average winter occupancy rate) x 292 (No. of units/complex)}} =$$

5.55 Kgal/household/month

5.55 Kgal x 94.6% (summer mo. avg. occupancy rate) x 292 (No. of Units =

1533 Kgals/month.

Step 4.

3010 Kgal (monthly average summer) - 1533 Kgal =

1477 Kgal/month

1477 Kgal/month x 6 months = 8862 Kgal

8862 Kgal ÷ 7.48 gal/cu. ft. ÷ 428,916 SF (9.85 acres) = 2.76' = 331"

There were 33.1" of domestic water applied for irrigation on the grounds of Newton Court housing complex during 1980 irrigation cycle.

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